Thesis/
Reports
Grant,
M. C.
1976

NUTRIENT MOVEMENT IN A MOUNTAIN WATERSHED SUPPORTING LIGHT RESIDENTIAL DEVELOPMENT 1976

Michael C. Grant

FINAL REPORT — 1st yr.

Nutrient Movement in a Mountain Watershed Supporting Light Residential Development

Eisenhower Consortium Project 16-529-CA

Drs. Michael C. Grant and William M. Lewis, Jr.

Department of E.P.O. Biology and

Institute of Arctic and Alpine Research

University of Colorado

Boulder, Colorado

April 30, 1976

L ARY

SEP 15 1976

ROCKY MOUNTAIN STATION

measure temperature and other variables within the watershed.

We have installed two standard 8" recording rain gauges with 8-day spring-wound clock drives on 8' receiving towers adjacent to Como Creek. One station is located near the upper end of MRS development above the area affected by human activity, while the other is located near the lower boundary of MRS property near the lower stream sampling station (Fig. 1). These gauges provide continuous chart record of precipitation. These data are supplemented with a third recording rain gauge routinely operated by the MRS on the north rim of the catchment basin.

To measure stream discharge, we installed a complete Parshall flume in the creek bed at the lower sampling station (Fig. 1). This flume was set on a bed of concrete and 4" x 4" timbers and is a permanent measuring device. A second discharge measuring station was established near the upper end of camp (Fig. 1) by constructing a stilling well apparatus in the 6' road culvert already present. The stilling well level measurements are supplemented by a lip-trough system which funnels low levels of flow through a small channel for more accurate measurement during periods of low flow. Calibration of both systems has been achieved by the use of electrical sump pumps to alter flow levels artificially by known amounts. Empirical curves for both discharge units have been constructed. The establishment of two discharge measuring systems enables us to quantify the amount of water added to the stream between the pristine and developed areas. This is especially important in identifying the source of differences in chemistry between the two locations. Both devices have operated well, even with the rather severe problems imposed by ice sheets and snow cover.

To obtain adequate precipitaiton samples for chemical work, we have constructed two large custom-designed precipitation collectors with

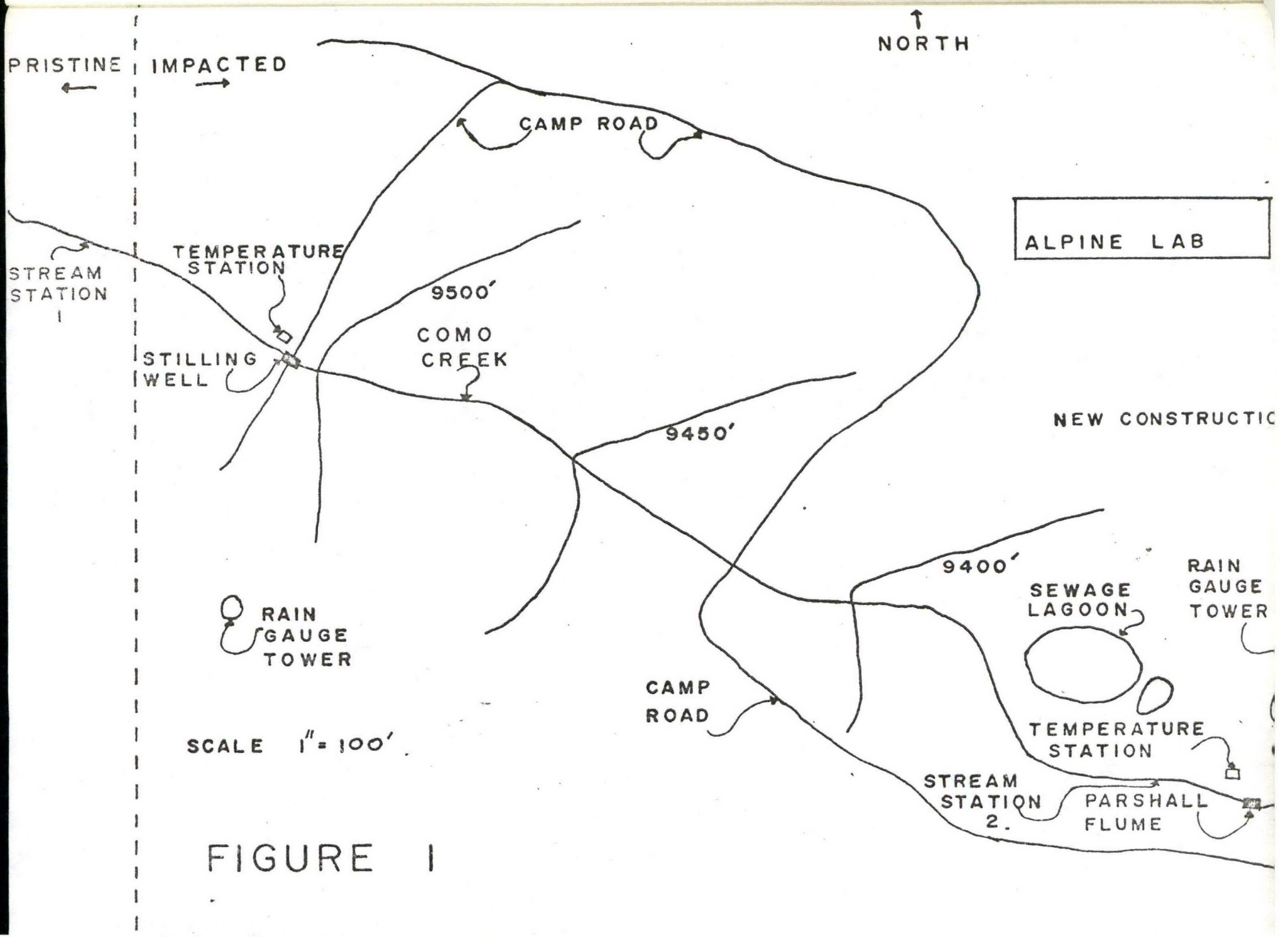

NORTH
PRISTINE
IMPACTED
CAMP ROAD
ALPINE LAB
STREAM STATION 1
TEMPERATURE STATION
9500'
COMO CREEK
STILLING WELL
NEW CONSTRUCTIO
9450'
9400'
SEWAGE LAGOON
RAIN GAUGE TOWER
RAIN GAUGE TOWER
CAMP ROAD
TEMPERATURE STATION
STREAM STATION 2.
PARSHALL FLUME
SCALE 1" = 100'

FIGURE 1

hard polypropylene plastic inlet funnels which feed into specially prepared borosilicate glass receiving vessels. Plastic screen mesh is used to trap coarse particulate matter before it enters the glass jars. These collection devices are mounted on the rain gauge towers mentioned above (Fig. 1). As we have made collections year round, temperature control inside the boxes has been a major factor. We have insulated 5 of the 6 sides of the collection boxes with styrofoam and installed 675 watts of heating lamps coupled to thermostats. These prevent freezing in the sample collection jar and keep snow melted on the receiving funnel. Such equipment would be difficult to operate without the utilities support of the MRS. The system has worked well down to at least -20°F. The large collecting surface area, approximately 650 sq. in., yields samples of precipitation large enough for analysis even when the amount of precipitation during the collection period is very small. We have established regular 110 V power outlet set-ups at each of the rain gauge stations plus power set-ups at the temperature recording stations (see below and Fig. 1). To do this, we ran nearly 1,000 feet of heavy duty outdoor electrical cable to the appropriate sites. We feel that the present system solves the major problem of quantifying nutrient input to watersheds--collection of sufficiently large samples for a complete range of chemical tests, regardless of weather.

The temperature measuring system, which was designed and constructed specifically for this project, constitutes a major equipment expenditure. This system consists of four solid state circuitry cards which interface four remote thermocouple temperature probes with two Dual-Channel Esterline Angus strip chart recorders. One setup is near the upper weir, the other near the lower one (Fig. 1). These devices provided continuous,

low response time measurement calibrated to read to the nearest 0.2°C on a scale from -25°C to +25°C. Air and stream water temperatures are monitored at each station continuously by these devices. Each equipment shelter box has been equipped with a heating lamp to prevent ink from freezing and other equipment problems due to the extremely low air temperatures under which they must operate.

III. Methods

A. Weather records. We have installed continuous air and water temperature monitors on the creek as described above. We also have wind and insolation records that are routinely taken by the station meterologist for the station as a whole. The 2 recording rain gauges situated beside the rain collectors on the precipitation towers at upper and lower stations provide us with duplicate records of the timing and amount of precipitation input.

B. Water temperatures. The temperatures are taken weekly with a thermometer or thermistor, and also recorded by the continuous monitors.

C. Flow rates. We presently measure flow rates weekly at both upper and lower stations by use of the weirs already described.

Chemical methods

We sampled both stream water and bulk precipitation at weekly intervals. Samples collected in the early morning were analyzed the same day except in a few cases for which preservation is completely safe. The precipitation collectors were rinsed with 500 cc of distilled water to remove dust or snow that had not yet entered the collecting bottles. The bulk precipitation sample was then diluted to 1 liter if necessary, as this is the minimum volume for complete battery of analyses. Dilution

proved unnecessary after we installed the custom-made high volume collectors. Correction for rinse water and dilution water were made in the computation stages. Lab procedure is as indicated in Fig. 2.

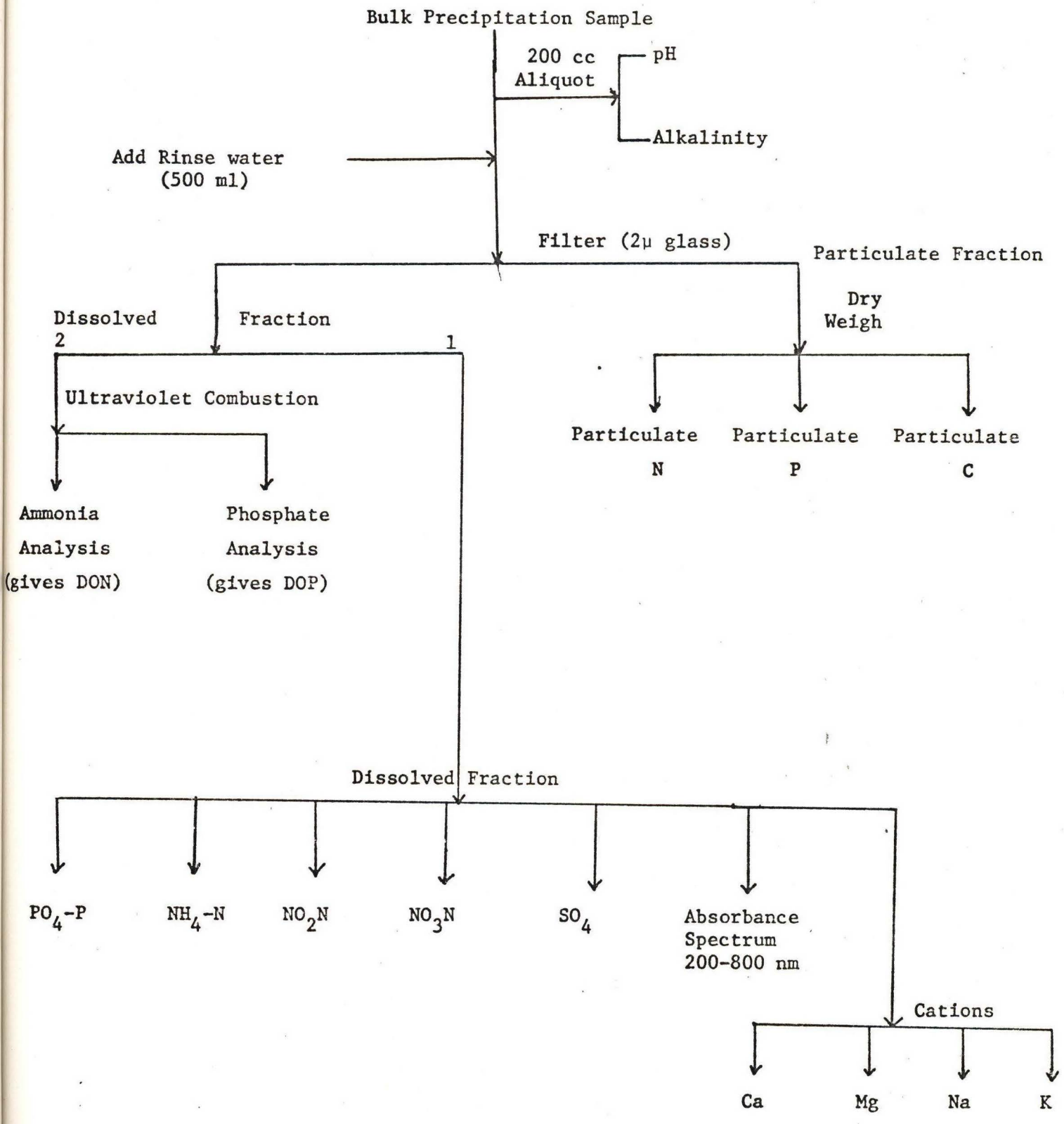
Analytical procedure for stream water and rain water are identical (Fig. 2), except rinse water is not involved for stream samples. In winter months, stream samples were at first aspirated through a tube that was permanently mounted in the stream and extended above the maximum snow level. We later replaced this method by inserting very large plastic tubes with removable lids into the snow so that the water surfaces could be observed during collection of a sample.

The analysis of the particulate fractions of stream water and bulk precipitation (dotted line enclosure, Fig. 2) has only recently been initiated and is as yet incomplete. These samples are in storage, however, and will be analyzed as the manpower becomes available.

The filtration of samples is carried out under vacuum with 2u glass fiber paper. Particulate fractions are dried on preweighed paper at 105°C and weighed, then stored under desiccation. Acid digestion of the particulate fraction was at first done with H_2SO_4 and Se under heat followed by neutralization with NaOH and a modified Solorzano technique (phenol-hypochlorite) for ammonia. The phosphorus in the digest was extracted in isobutanol and analyzed by a tin chloride method. More recently we have moved to the use of a Hg catalyst which solves some problems with the Solorzano test.

In the dissolved fraction, a cation aliquot is treated with nitric acid and analyzed by atomic absorption. Sulfate is determined by barium precipitation. A complete absorbance spectrum is run to indicate DOC content. Nitrogen is analyzed as (1) nitrate, by reduction to nitrite with a cadmium-copper couple and subsequent formation of an azo dye with

Fig. 2 Analytical procedure for analysis of bulk precipitation reaching the watershed of Como Creek. Procedure for stream water is the same except no rinse water is added.



nitrite; (2) nitrite, by azo dye formation prior to reduction; (3) ammonia, by a Solorzano method; (4) primary amines, by use of a fluorescing compound specific for amines (this technique is very new and we have had some problems with it); (5) total dissolved organic N, determined by combustion of the organic complexes with UV light converting organic N to ammonia. Phosphorous is separated into orthophosphate, determined by citric acid method, and dissolved organic P, determined by UV combustion. Alkalinity is determined by titration with standard acid, and pH is measured with a pH meter.

IV. Results

We have at this time not quite completed a year of field work, but some major patterns are already clear.

A. Discharge. Discharge at the upper station is shown in Fig. 3. The lower station, which is located .5 km downstream from station 1, has a slightly higher discharge. The seasonal pattern is as follows:

1. Maximum discharge during June and early July, due to snowmelt.
2. Very rapid decline of discharge in July.
3. Slow but continuous decline of discharge in August and September.
4. Minimum discharge under snow during November - April.
5. Rapid increase of discharge in May due to snowmelt (we have not yet completed the May data collection but it is clear that this will happen).

Maximum and minimum flow differ by a factor of 1000 or more.

B. Water temperature. Figure 4 shows the seasonal water temperature trend. Maximum temperatures occur in late summer and do not exceed $10^{o}C$. There is a marked cooling trend in September that brings the temperatures near the freezing point.

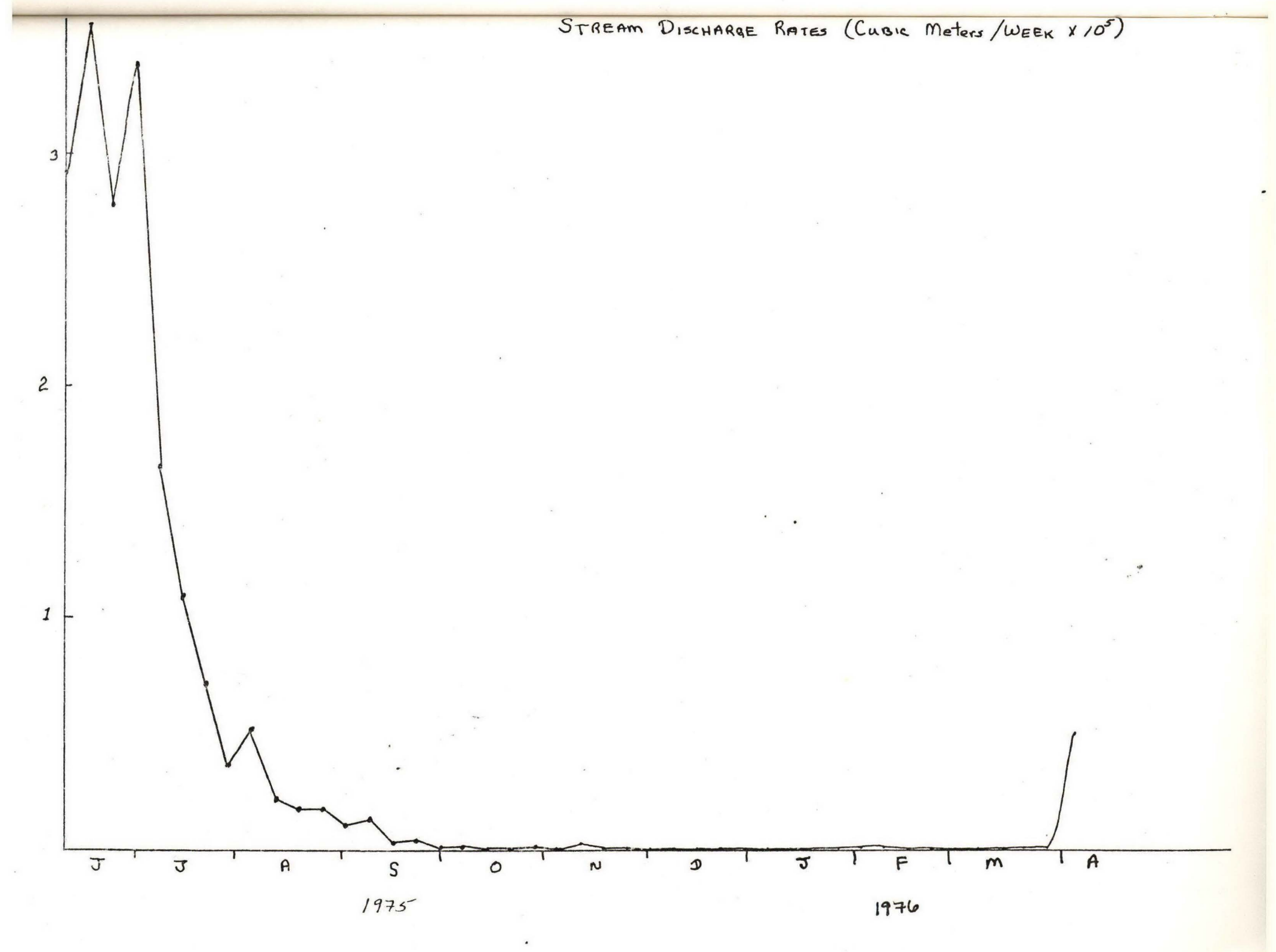
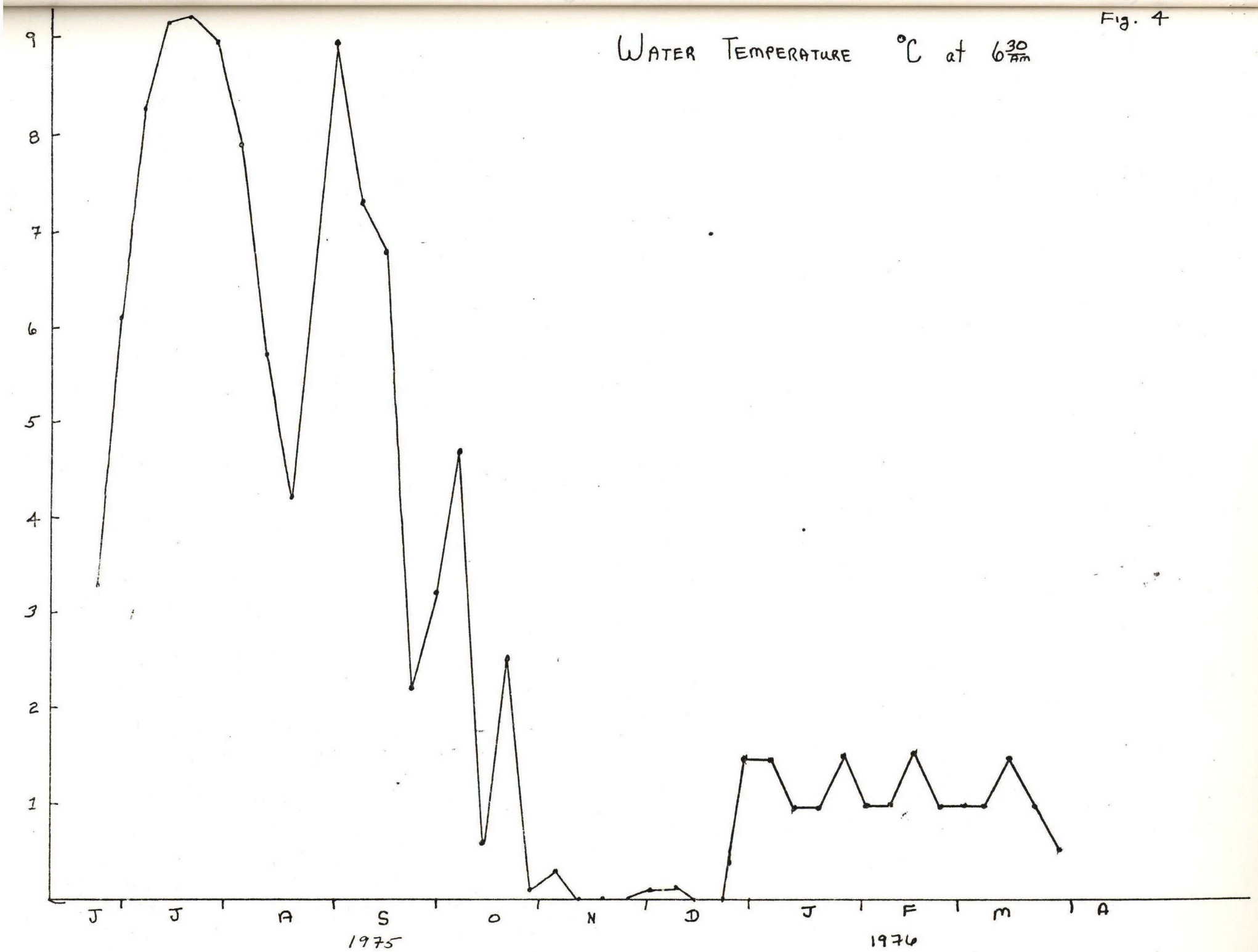

STREAM DISCHARGE RATES (CUBIC METERS/WEEK X 10^5)
3
2
1
J
J
A
S
O
N
D
J
F
M
A
1975
1976

Fig. 4


WATER TEMPERATURE °C at 6 30 Am
9
8
7
6
5
4
3
2
1
J
J
A
S
O
N
D
J
F
M
A
1975
1976

By comparison with most freshwater bodies, the annual temperature fluctuation of this stream is extremely low, as is evident in Fig. 4.

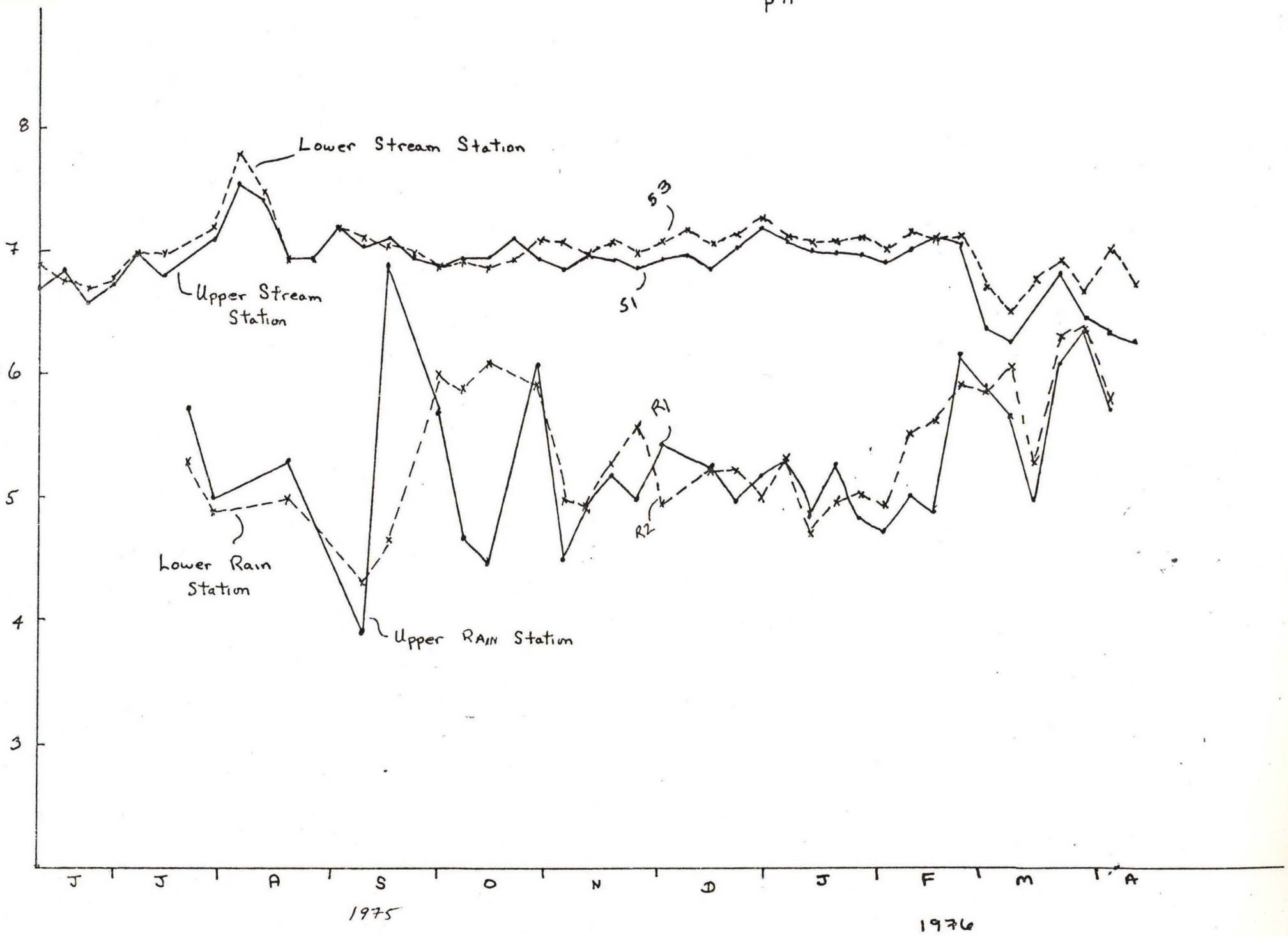
C. pH and alkalinity. The stream is very near neutrality most of the year (Fig. 5). There is a definite tendency toward acidity during snowmelt. We now believe that this phenomenon is explained by the drastic increase of organic acids in the water during periods of snowmelt. Because the water is poorly buffered, these acids have a marked effect on the pH of the stream. The acids are of natural terrestrial origin.

Precipitation is always acidic, both as rain and snow, and varies somewhat irregularly as expected due to poor buffering (Figs. 5, 6). Quite acidic rains and snows with a pH near 4.0 were observed on several occasions (Fig. 5).

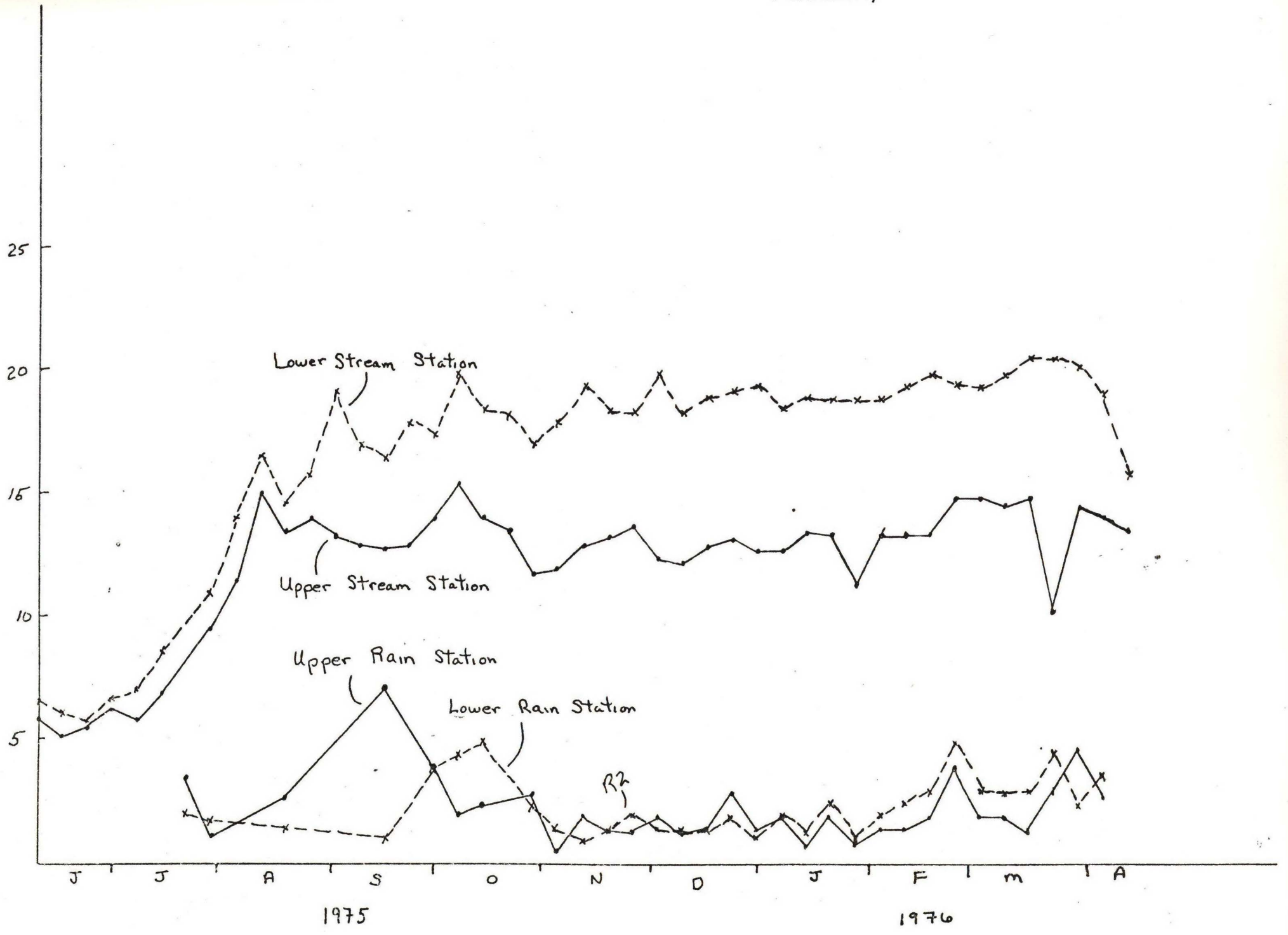
Stream water at the upper station has lower alkalinity than the lower station. The upper station drains only undisturbed mountain woodland, whereas the lower station drains the Mountain Research Station development as well. We tentatively view the higher alkalinity at the lower station as an effect of soil and vegetation disturbance caused by the station. This also explains the higher pH at the lower station. The alkalinity effect is quite marked and can be observed at any time of year.

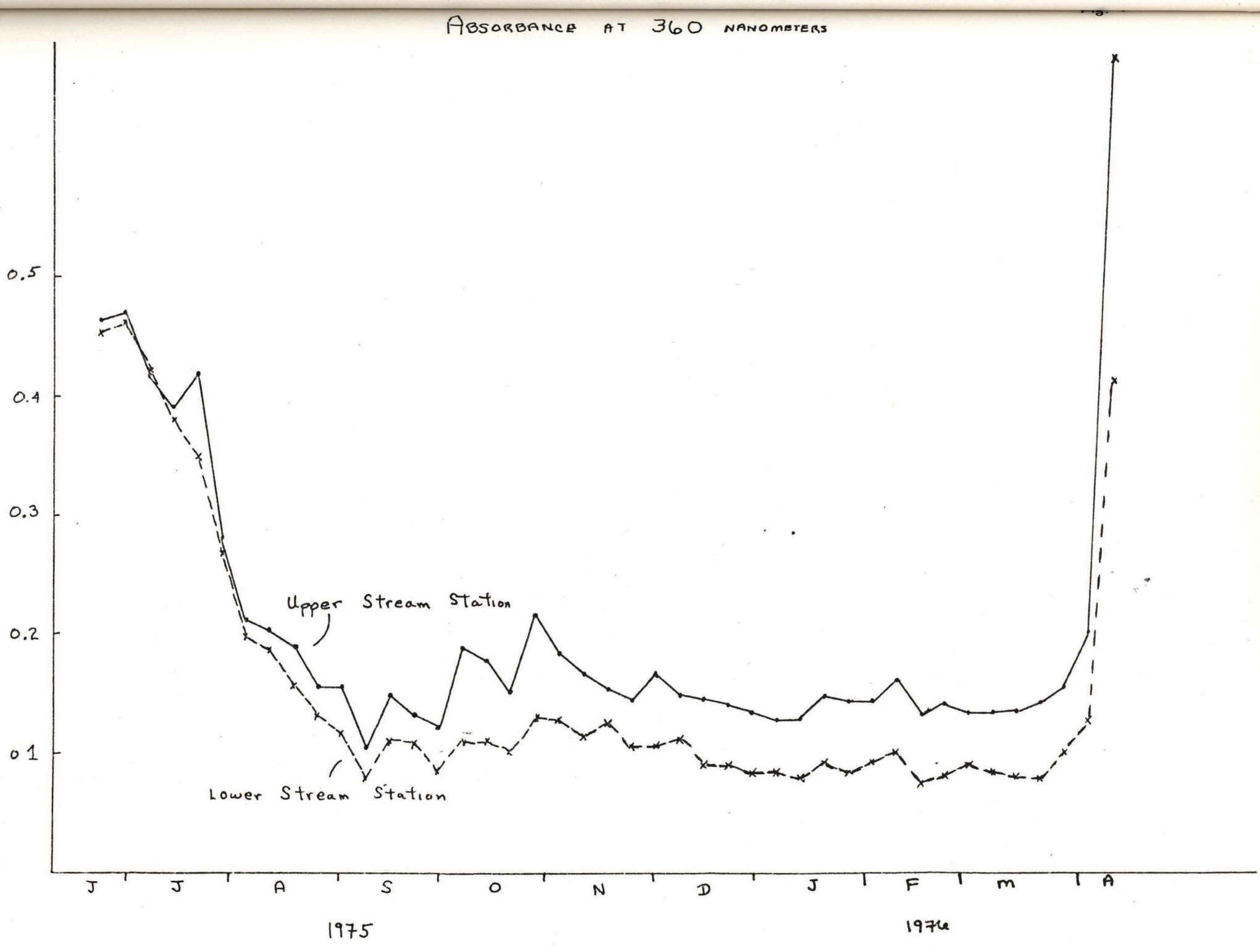
D. Absorbance spectrum. Absorbance of light at 360 nm, which is a good indication of dissolved organic carbon levels, declines as discharge declines, indicating a drastic reduction in loss of dissolved organics from the watershed as snowmelt declines (Fig. 7). Mechanisms involved here are not yet clear but are likely to be very important to the nutrient economy of the stream. The upper station shows a continuously higher absorbance, indicating that the source of the organics is the pristine woodland but that these components are either diluted or

Fig. 5


pH
8
7
6
5
4
3
Lower Stream Station
S3
Upper Stream Station
S1
R1
R2
Lower Rain Station
Upper RAIN Station
J
J
A
S
O
N
D
J
F
M
A
1975
1976

ALKALINITY


25
20
15
10
5
Lower Stream Station
Upper Stream Station
Upper Rain Station
Lower Rain Station
R2
J
J
A
S
O
N
D
J
F
m
A
1975
1976


ABSORBANCE AT 360 NANOMETERS
0.5
0.4
0.3
0.2
0 1
Upper Stream Station
Lower Stream Station
J
J
A
S
O
N
D
J
F
m
A
1975
1976

chemically changed as they pass the MRS development. We believe that cations added in the developed stretch of the watershed precipitate the organic acids and thus cause a decline in absorbance. We consider this to be a significant finding.

E. Phosphorous compounds. Orthophosphate levels in the stream are extremely low, as expected, and show a surprisingly small seasonal trend (Fig. 8). The difference between stations is considerable, and the lower station is always higher, indicating a substantial effect from MRS on P input. The amount of ortho-P is greatest under ice and snow cover, probably due to the reduced autotrophic demand under these conditions.

Dissolved organic P is also low but at least as significant quantitatively as ortho-P. The station difference is not pronounced for organic forms of P (Fig. 9). DOP is greatest at times of snowmelt.

The amounts of P in bulk precipitation frequently exceed the amounts in the streams (Figs. 10, 11). The wet spring snows are amazingly high in phosphorus and this may be a major biological influence on both watershed and stream autotrophs. The replicates at the two stations show all the same major trends, indicating that the observed variations are indeed due to real changes in the P input.

F. Nitrogen compounds. Nitrite is routinely very low in the stream water as expected (Fig. 12). Amounts found in rain can be considerable, however.

Nitrate is present at low levels in stream water at the upper station, but much higher levels are observed at the lower station (Fig. 13). This is evidently a very striking effect of the MRS development and is high enough to have substantial effects on the biota.

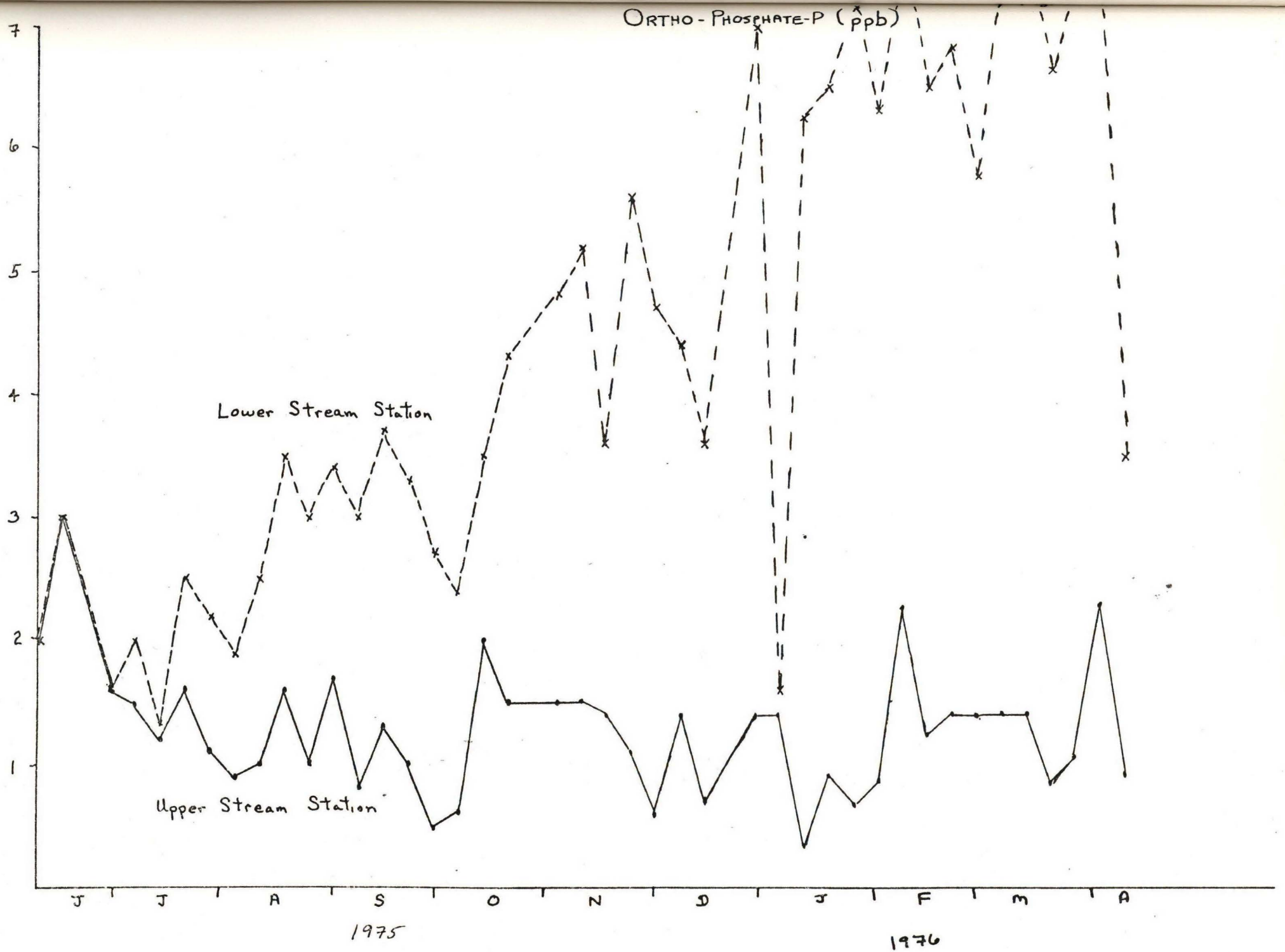
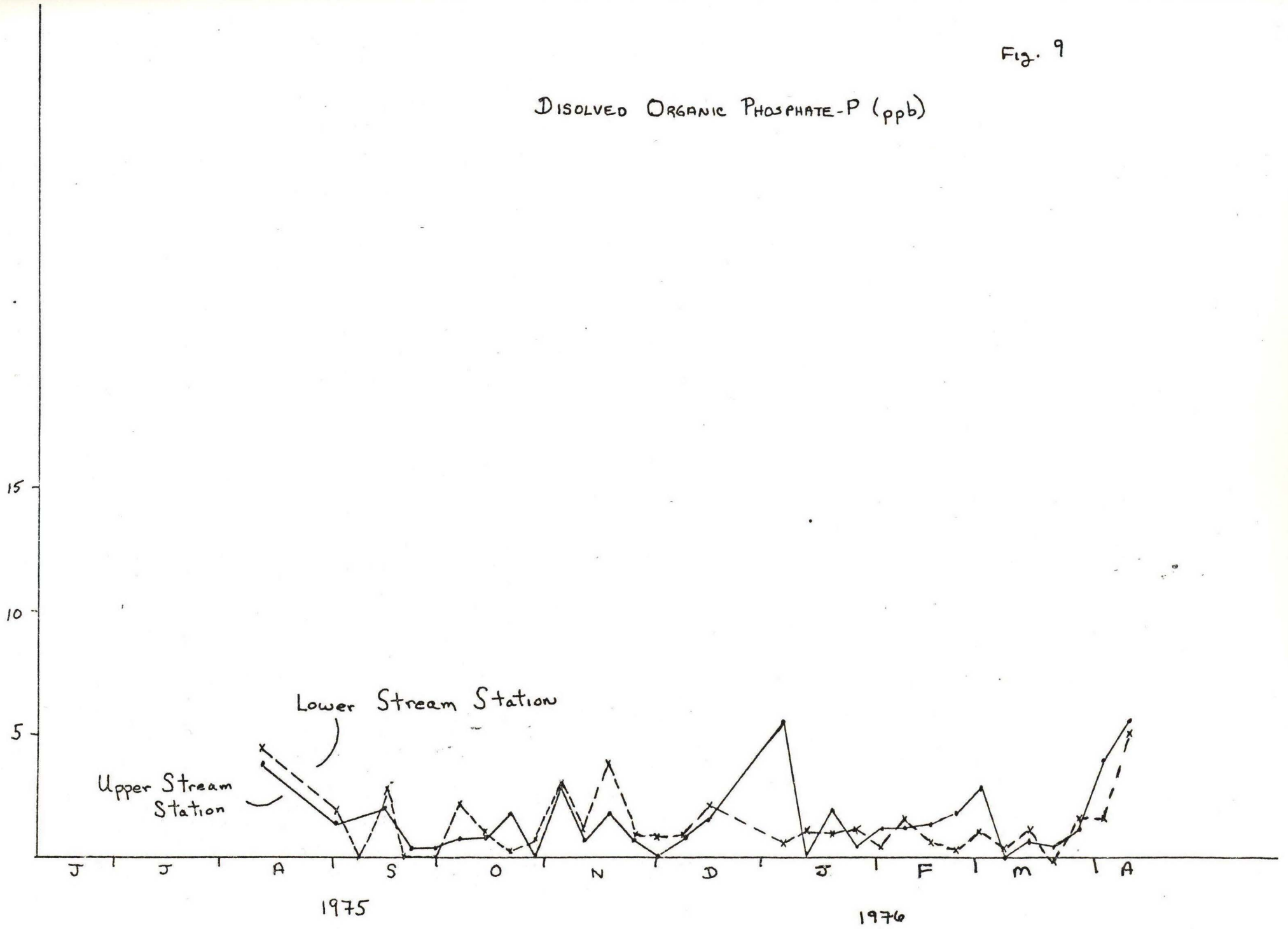
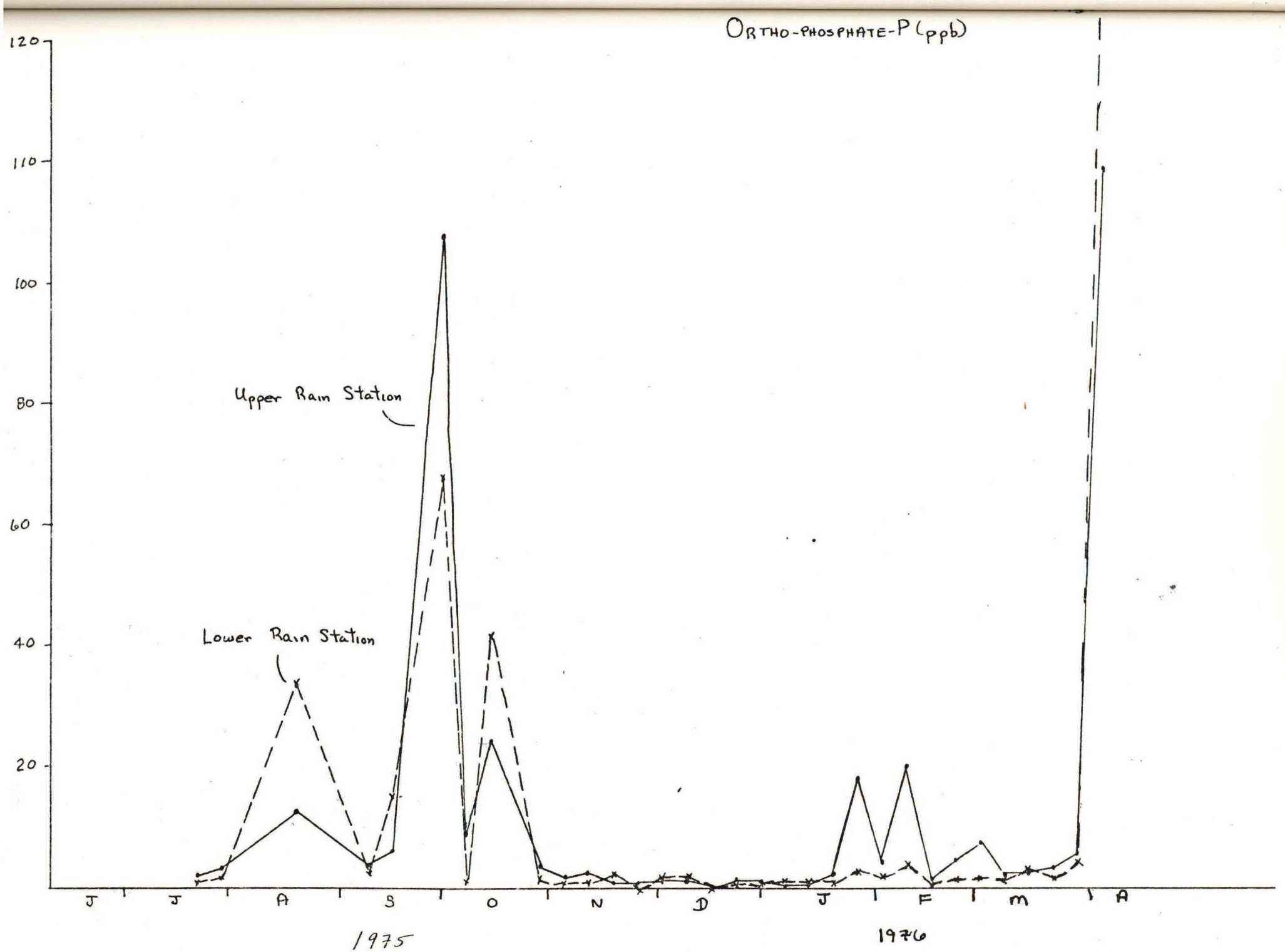

ORTHO-PHOSPHATE-P (ppb)
7
6
5
4
3
2
1
Lower Stream Station
Upper Stream Station
J
J
A
S
O
N
D
J
F
M
A
1975
1976

Fig. 9

DISOLVED ORGANIC PHOSPHATE-P (ppb)




ORTHO-PHOSPHATE-P (ppb)
120
110
100
80
60
40
20
Upper Rain Station
Lower Rain Station
J
J
A
S
O
N
D
J
F
M
A
1975
1976

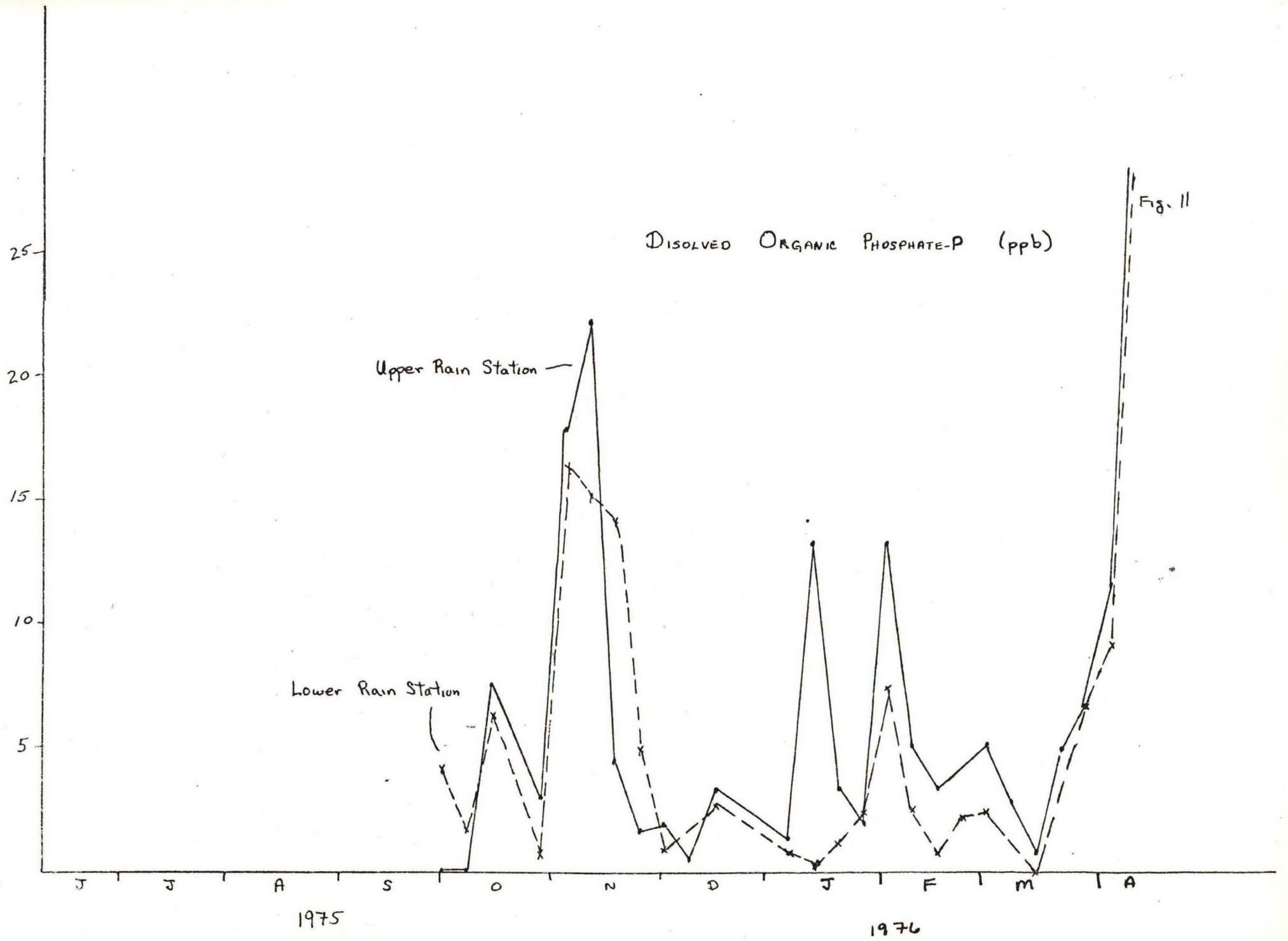
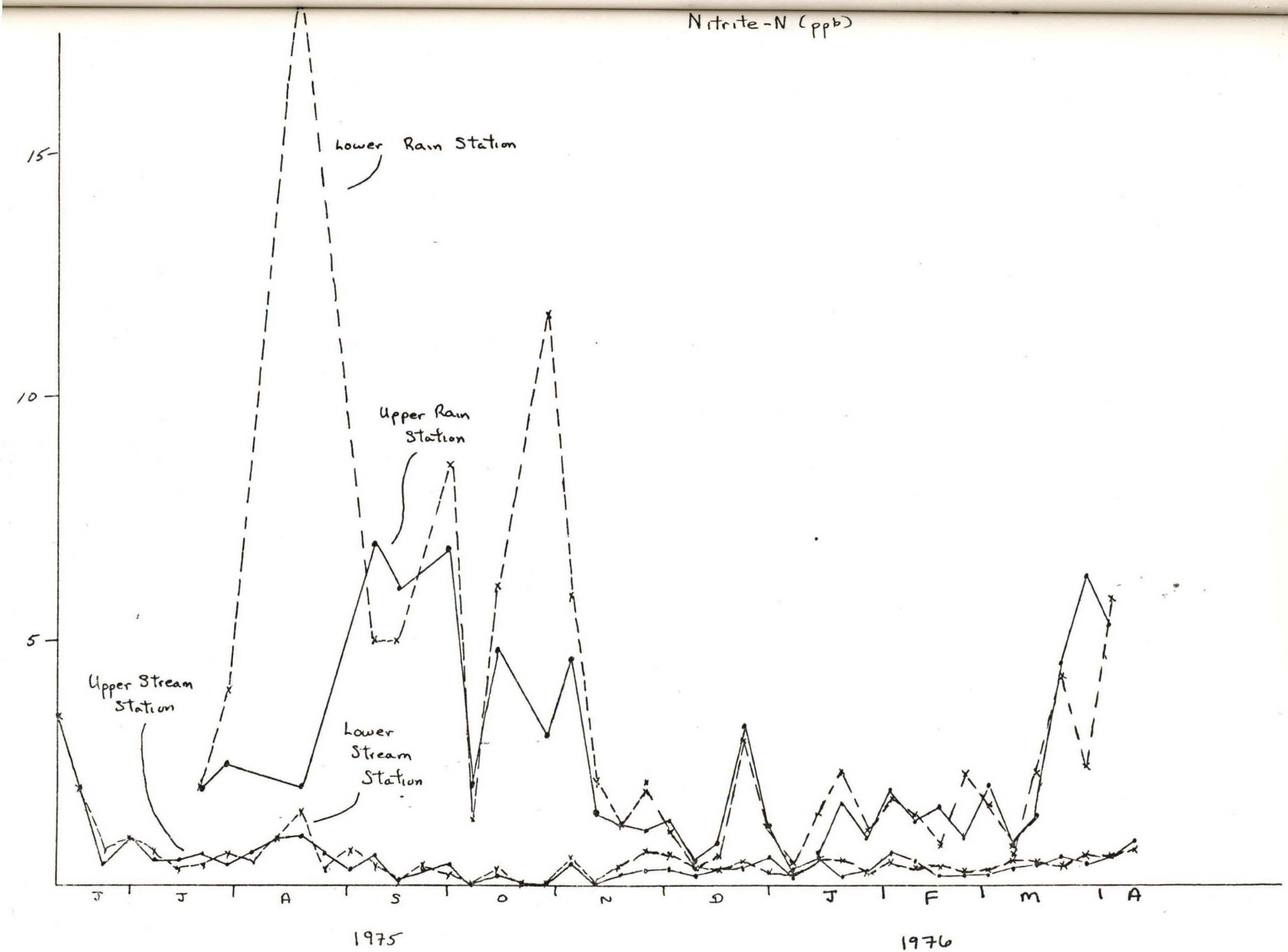
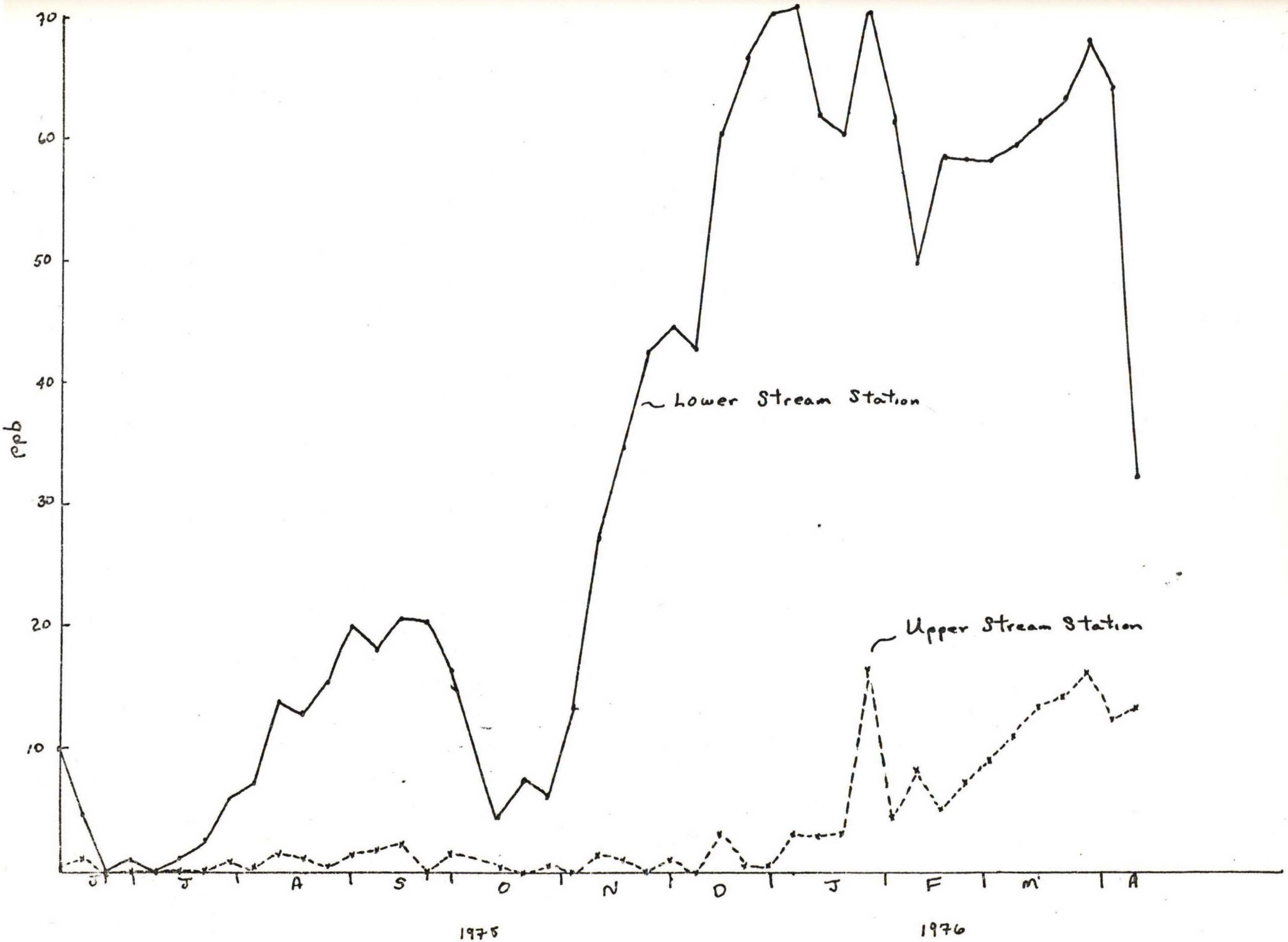


Fig. 11
Disolved Organic Phosphate-P (ppb)
Upper Rain Station
Lower Rain Station
25
20
15
10
5
J
J
A
S
O
N
D
J
F
M
A
1975
1976


Nitrite-N (ppb)
15
10
5
Lower Rain Station
Upper Rain Station
Upper Stream Station
Lower Stream Station
J
J
A
S
O
N
D
J
F
M
A
1975
1976


70
60
50
40
30
20
10
ppb
Lower Stream Station
Upper Stream Station
J
J
A
S
O
N
D
J
F
m
A
1975
1976

The autotrophs are very likely to be nitrogen starved under pristine conditions, due to the very low levels of available N. The MRS development changes this situation radically.

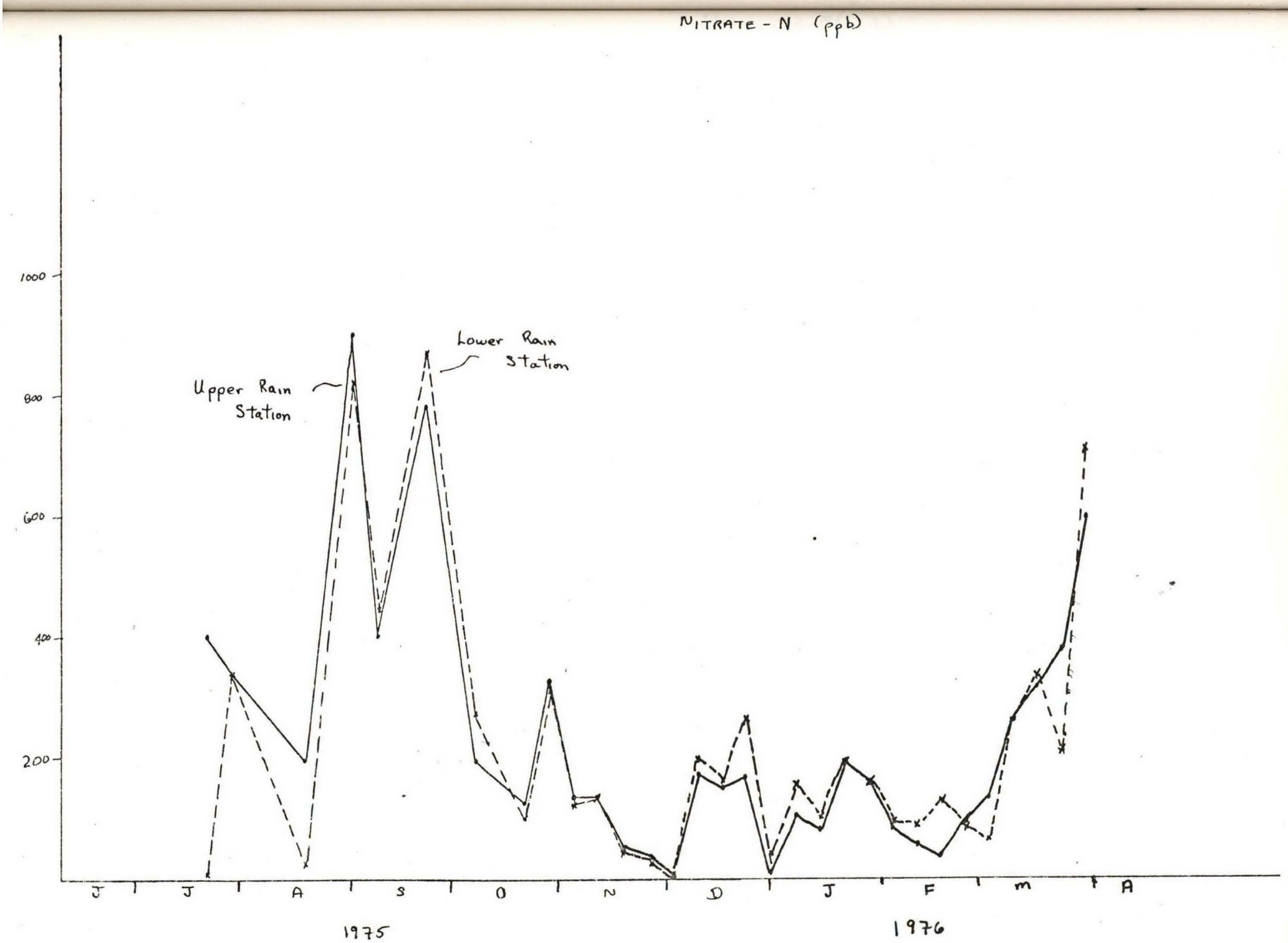
Nitrate in rain is 1-2 orders of magnitude above stream concentrations (Fig. 14). Obviously N input as nitrate in rain is very significant to the system.

For ammonia in streamwater, the two stations are essentially identical. This suggests that the MRS effect is specific for NO_3^-, which is reasonable in view of the much greater mobility of NO_3^- in soils (Fig. 15).

There is a striking rise in fall ammonia levels that will be of great interest next year (Fig. 15). Rain input of ammonia is very high and variable (Fig. 16), and a very important means of N input to the system. As with nitrate, we see a marked spring peak. Dissolved organic N is a significant component of the total N entering and leaving the system (Figs. 17, 18). DON seems to be slightly higher at the upper than the lower station, which fits with absorbance data.

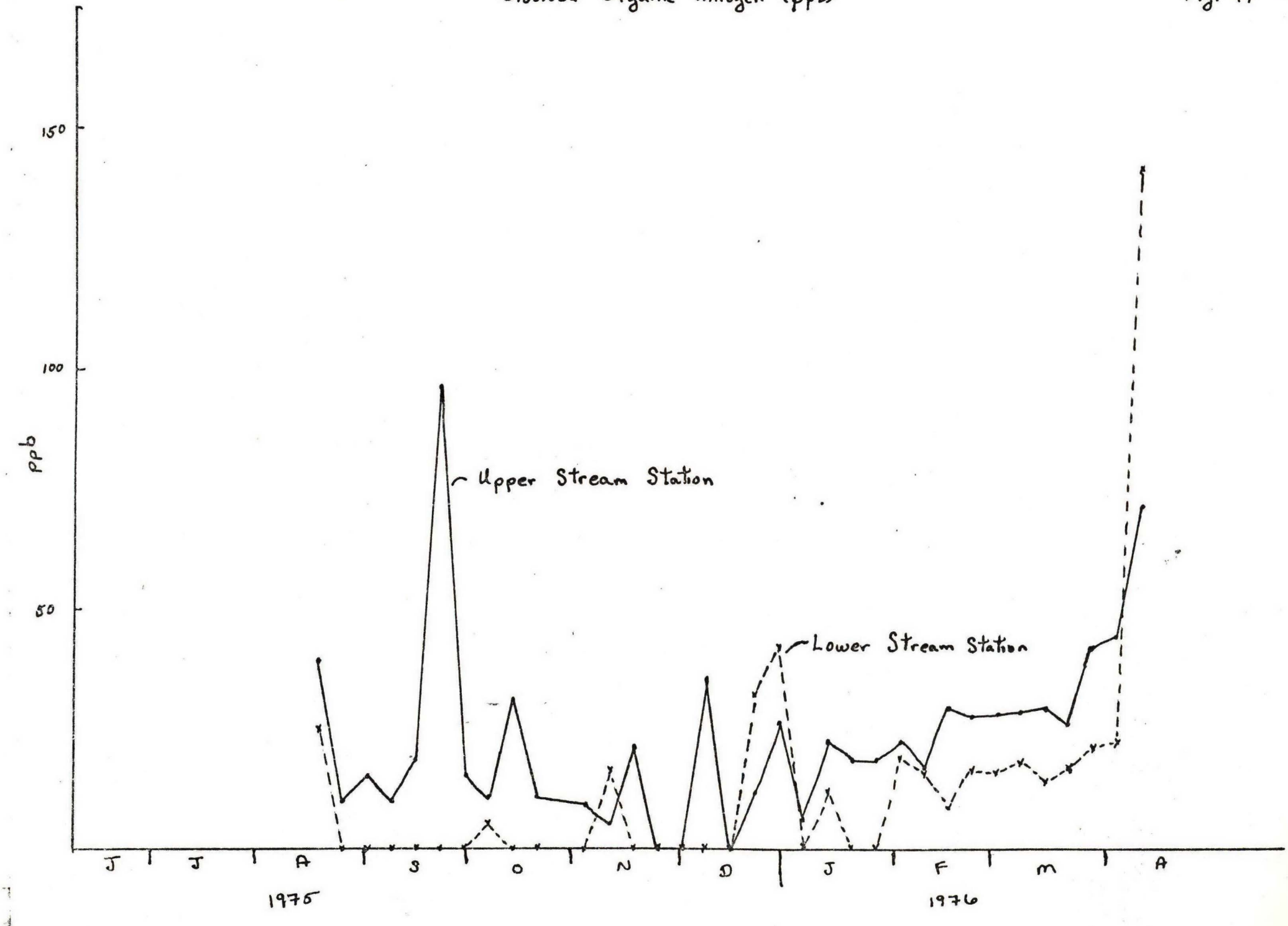
G. Sulfate. Sulfate in the stream water and rain is low and frequently is exceeded by the amounts in precipitation (Figs. 19, 20). The lower stream station averages lower than the upper station, which is an unexpected MRS effect which is more difficult to explain than the other effects we have documented here.

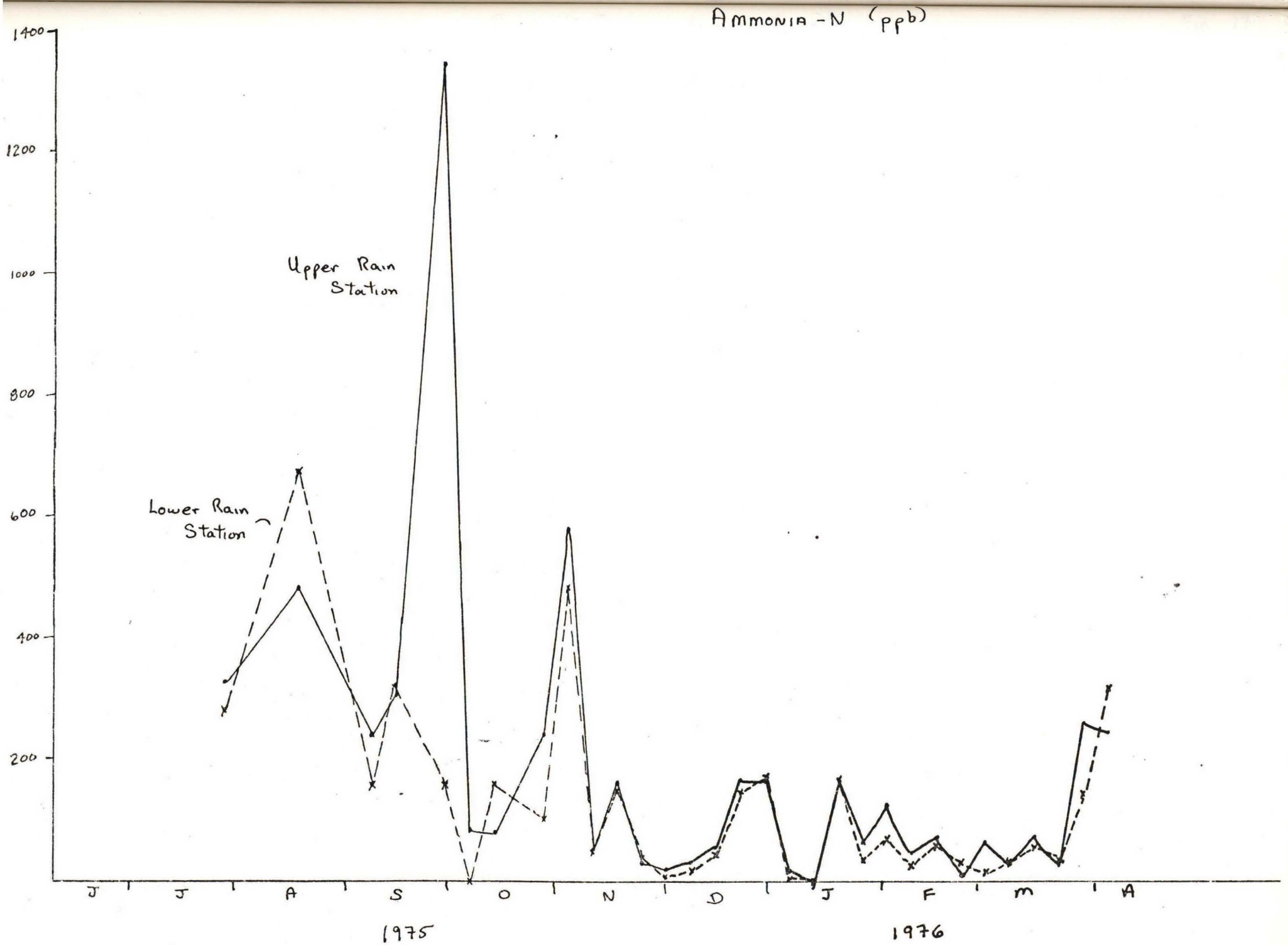
H. Cations. All major cations follow an upward trend in streamwater toward fall and show a strong station effect (Fig. 21). Percentage differences are greatest in potassium, which was at times 50% higher at the lower station. The difference is most likely attributable to the MRS development. The greater concentrations of cations play a role in the observed reductions of dissolved organics at the lower station, as


NITRATE - N (ppb)
1000
800
600
400
200
Upper Rain Station
Lower Rain Station
J
J
A
S
O
N
D
J
F
m
A
1975
1976

Dissolved Organic Nitrogen (ppb)

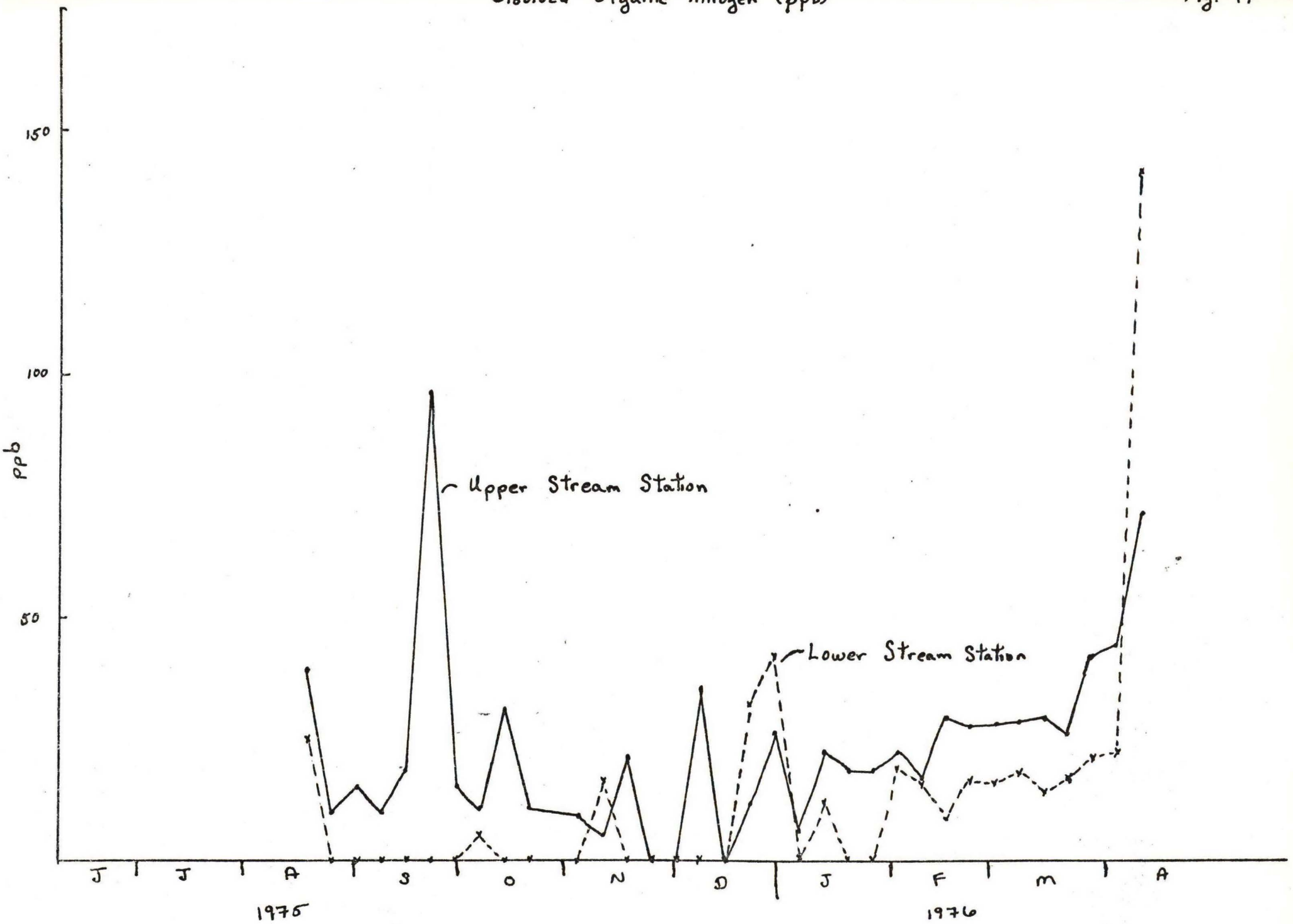
Fig. 17

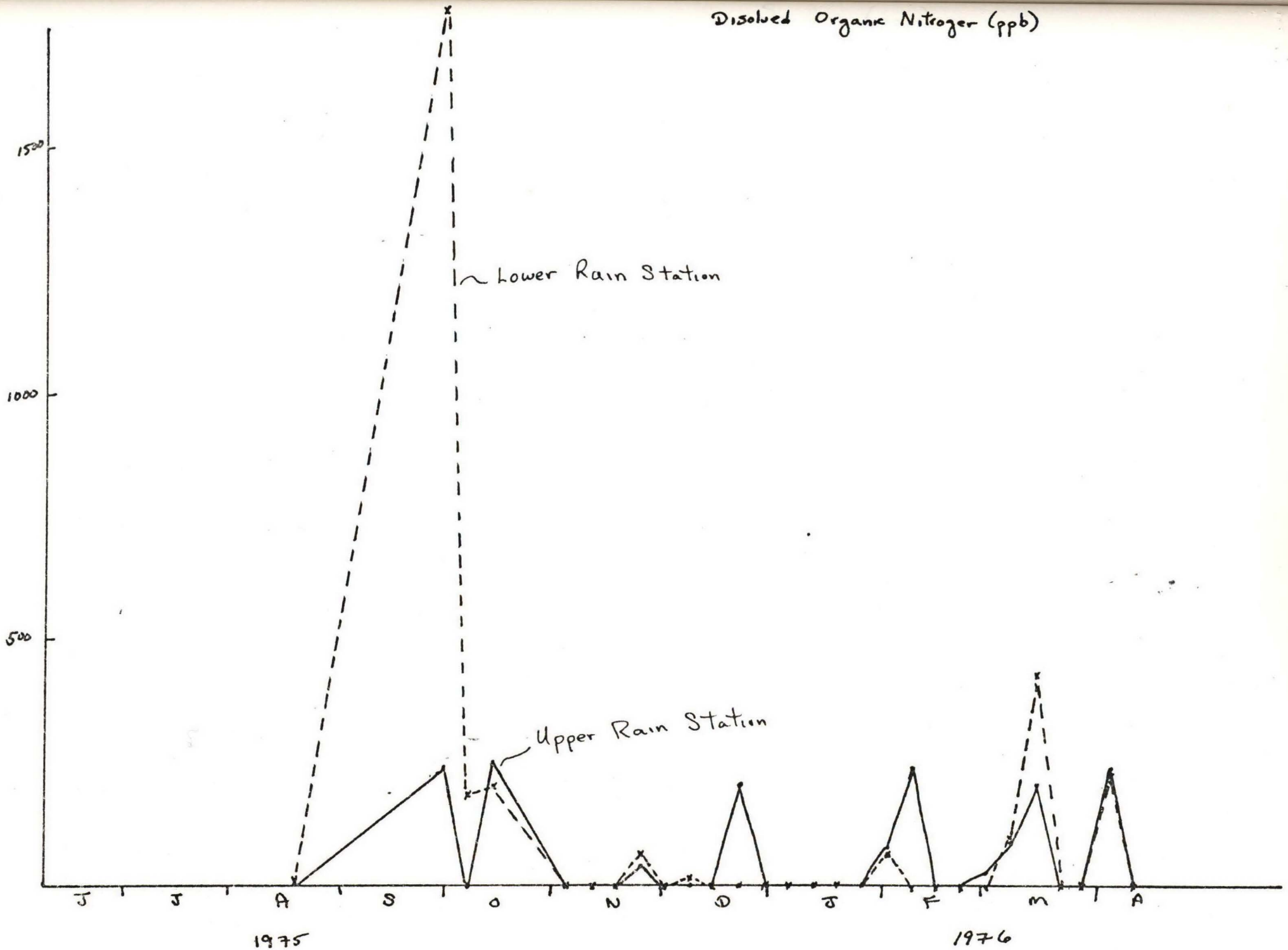


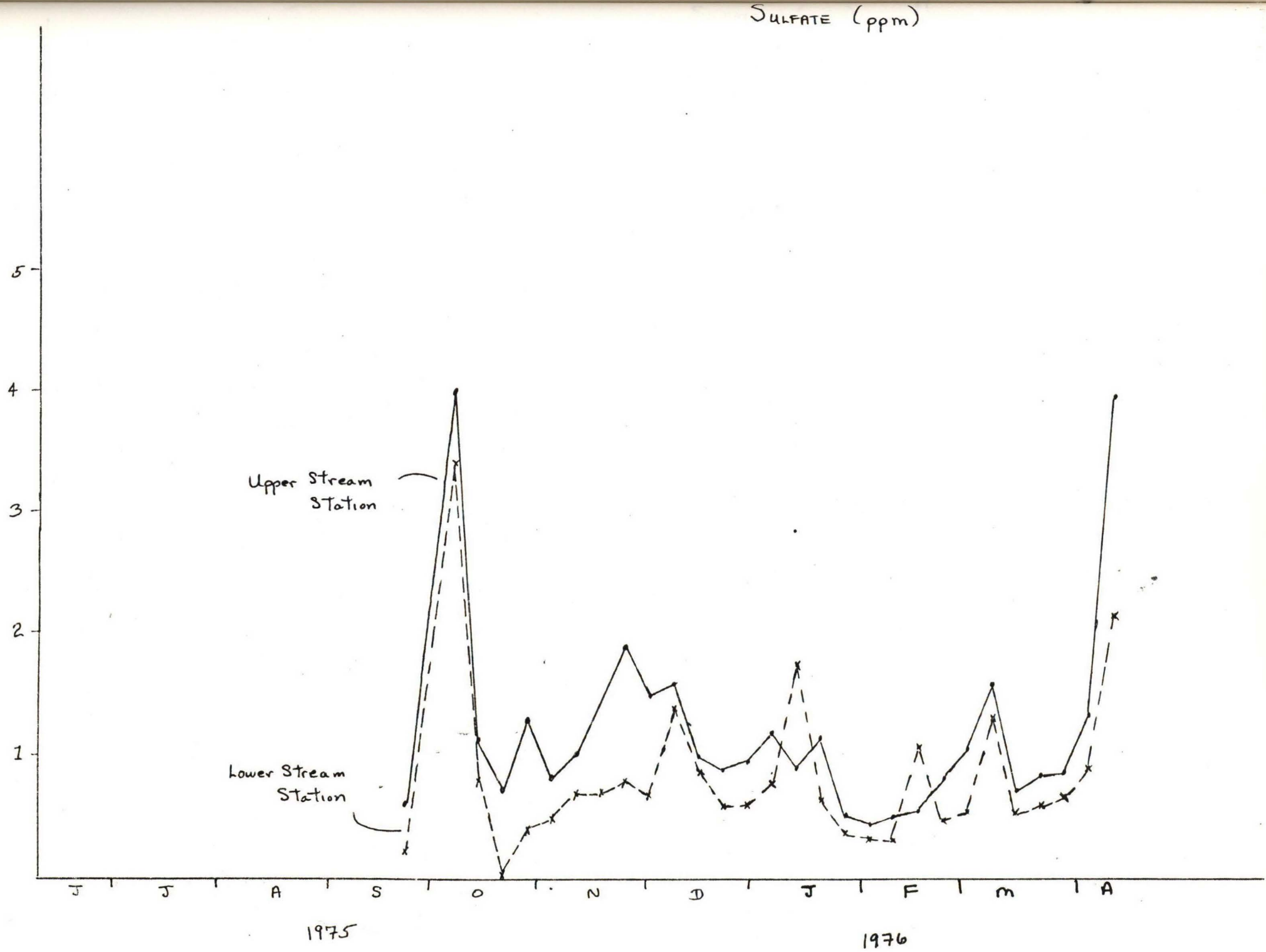

AMMONIA - N (ppb)
1400
1200
1000
800
600
400
200
Upper Rain Station
Lower Rain Station
J
J
A
S
O
N
D
J
F
M
A
1975
1976

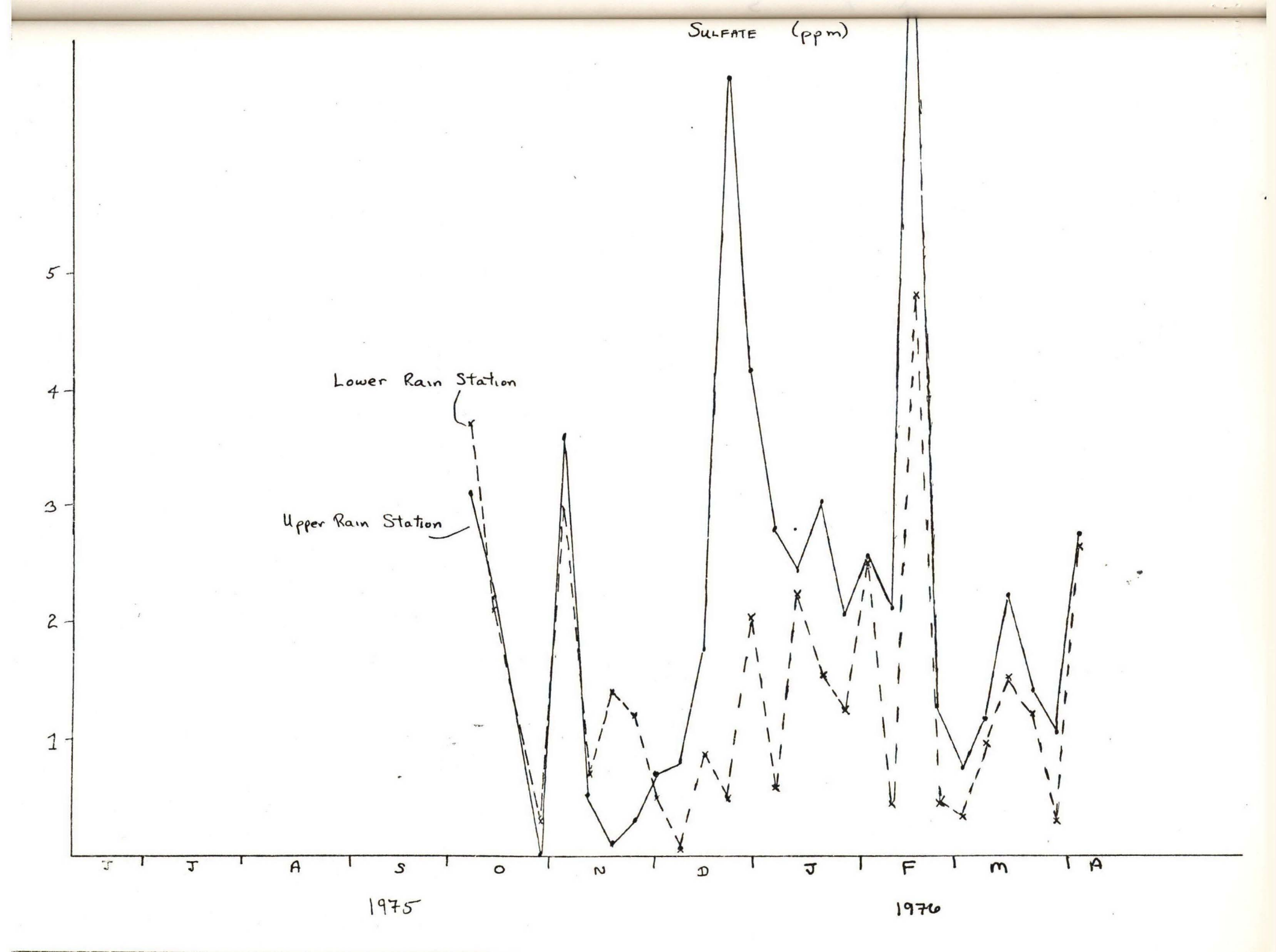
Dissolved Organic Nitrogen (ppb)

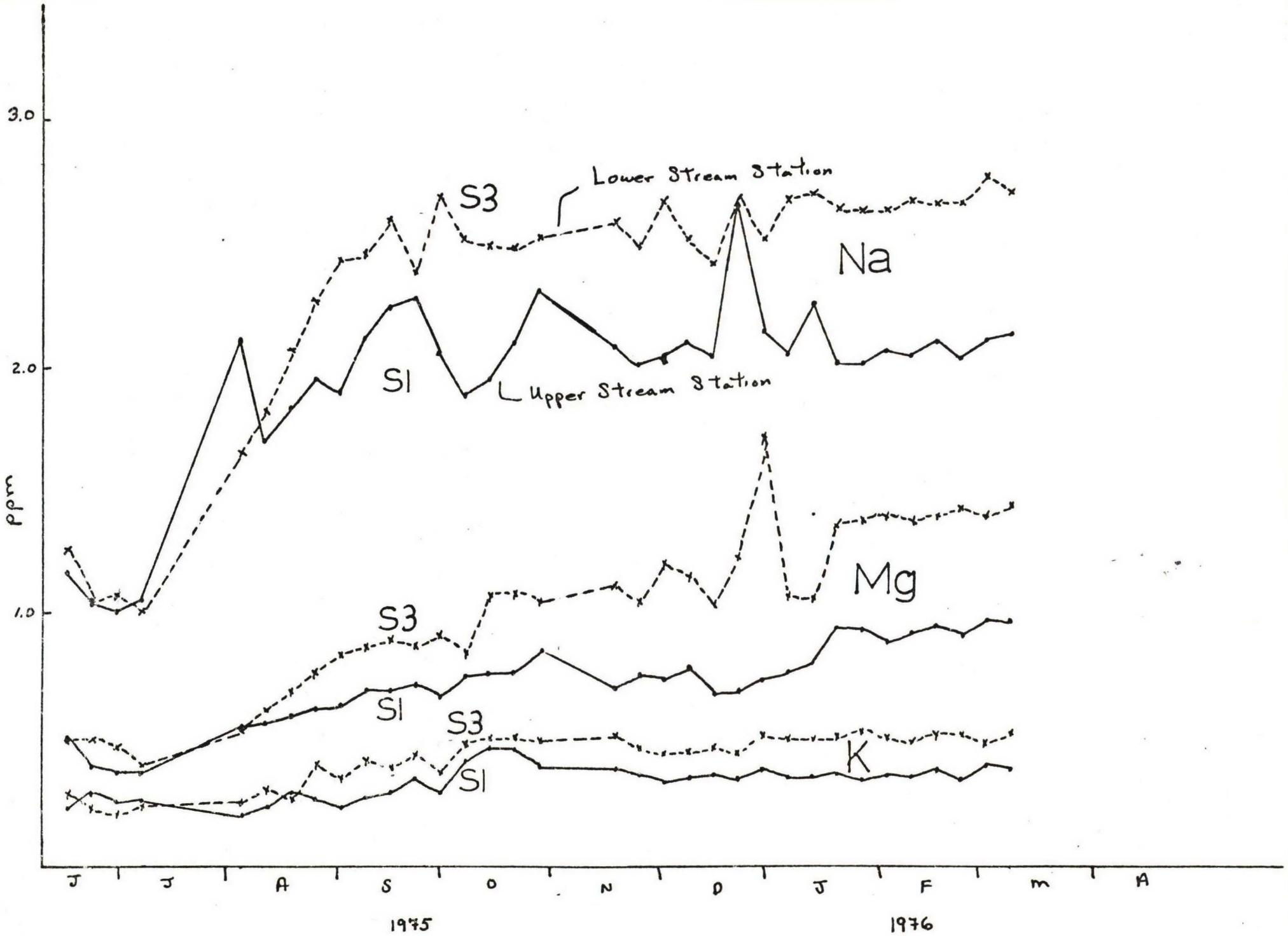
Fig. 17

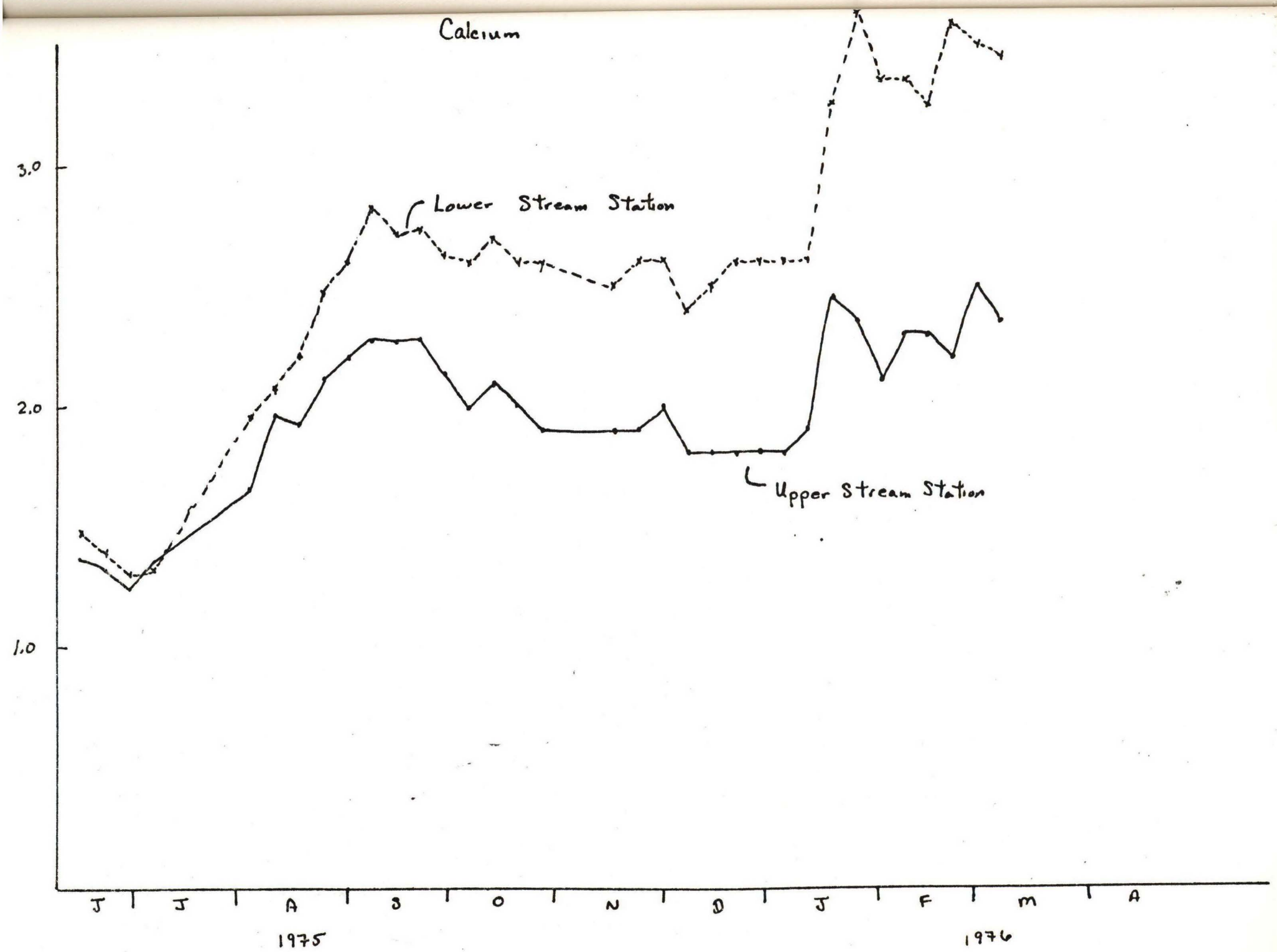



Dissolved Organic Nitrogen (ppb)
1500
1000
500
Lower Rain Station
Upper Rain Station
J
J
A
S
O
N
D
J
F
M
A
1975
1976


Sulfate (ppm)
5
4
3
2
1
Upper Stream Station
Lower Stream Station
J
J
A
S
O
N
D
J
F
m
A
1975
1976

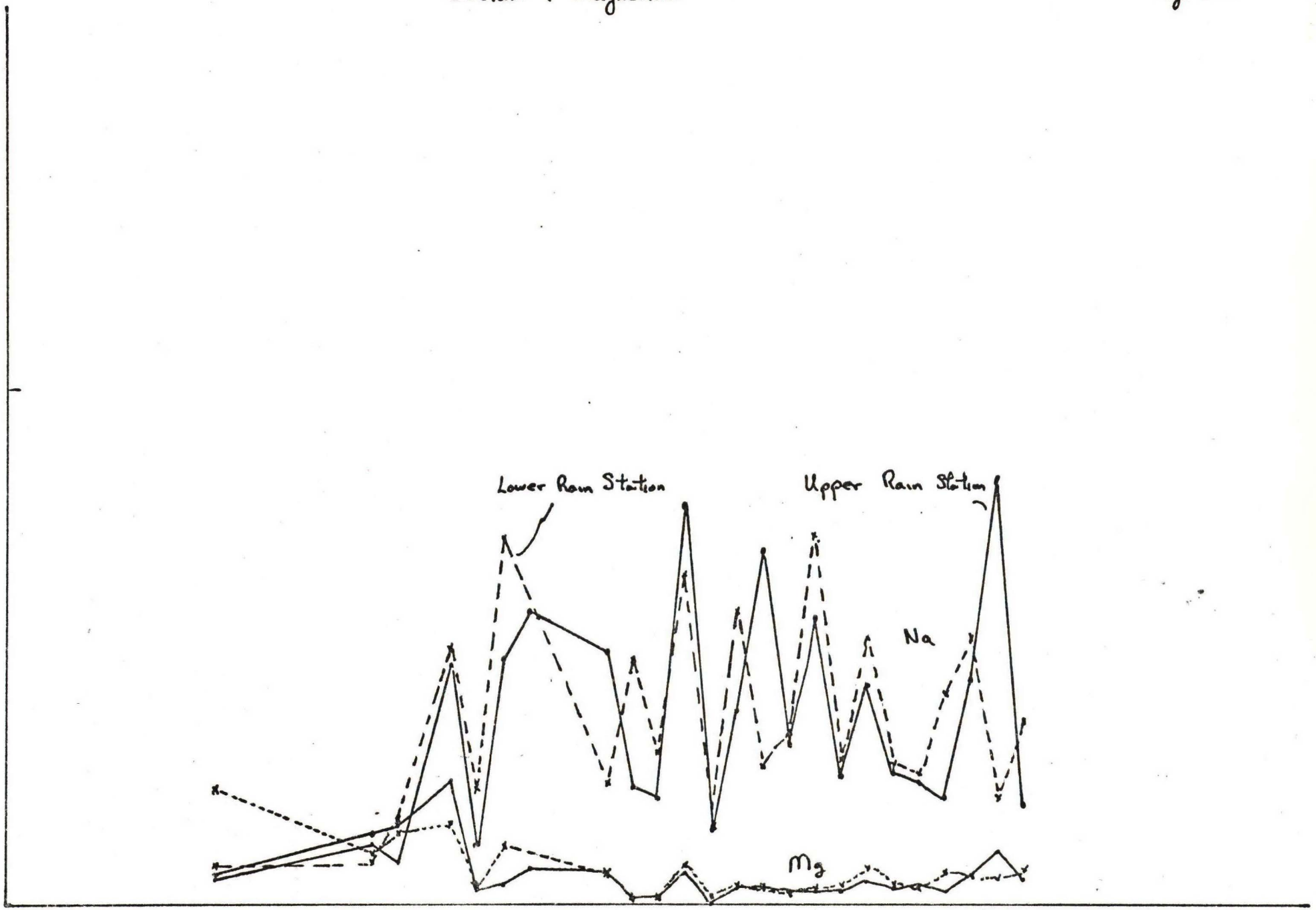

SULFATE (ppm)
Lower Rain Station
Upper Rain Station
5
4
3
2
1
J
J
A
S
O
N
D
J
F
M
A
1975
1976

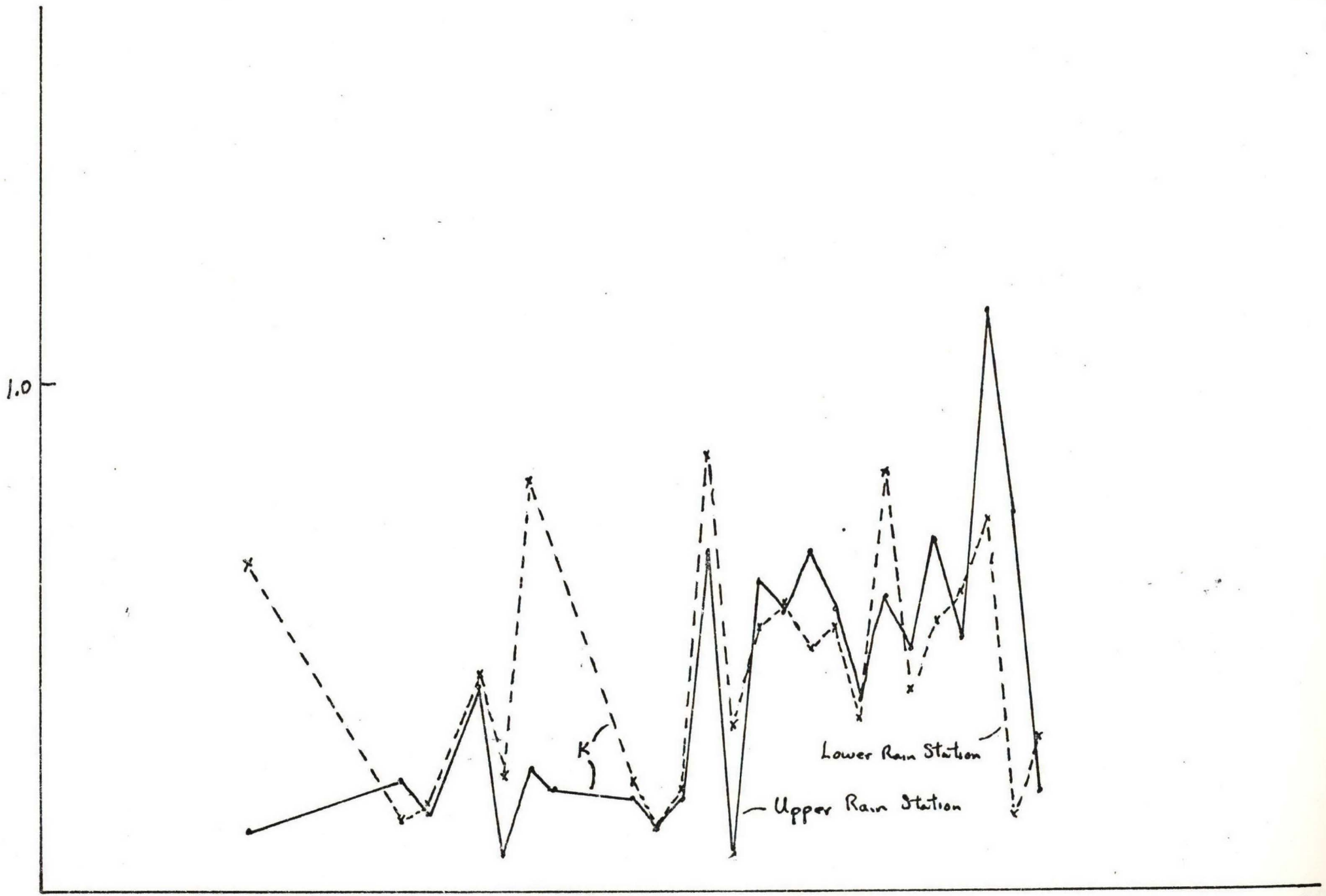

3.0
2.0
1.0
ppm
S3
Lower Stream Station
Na
S1
Upper Stream Station
Mg
S3
S1
S3
K
S1
J
J
A
S
O
N
D
J
F
m
A
1975
1976

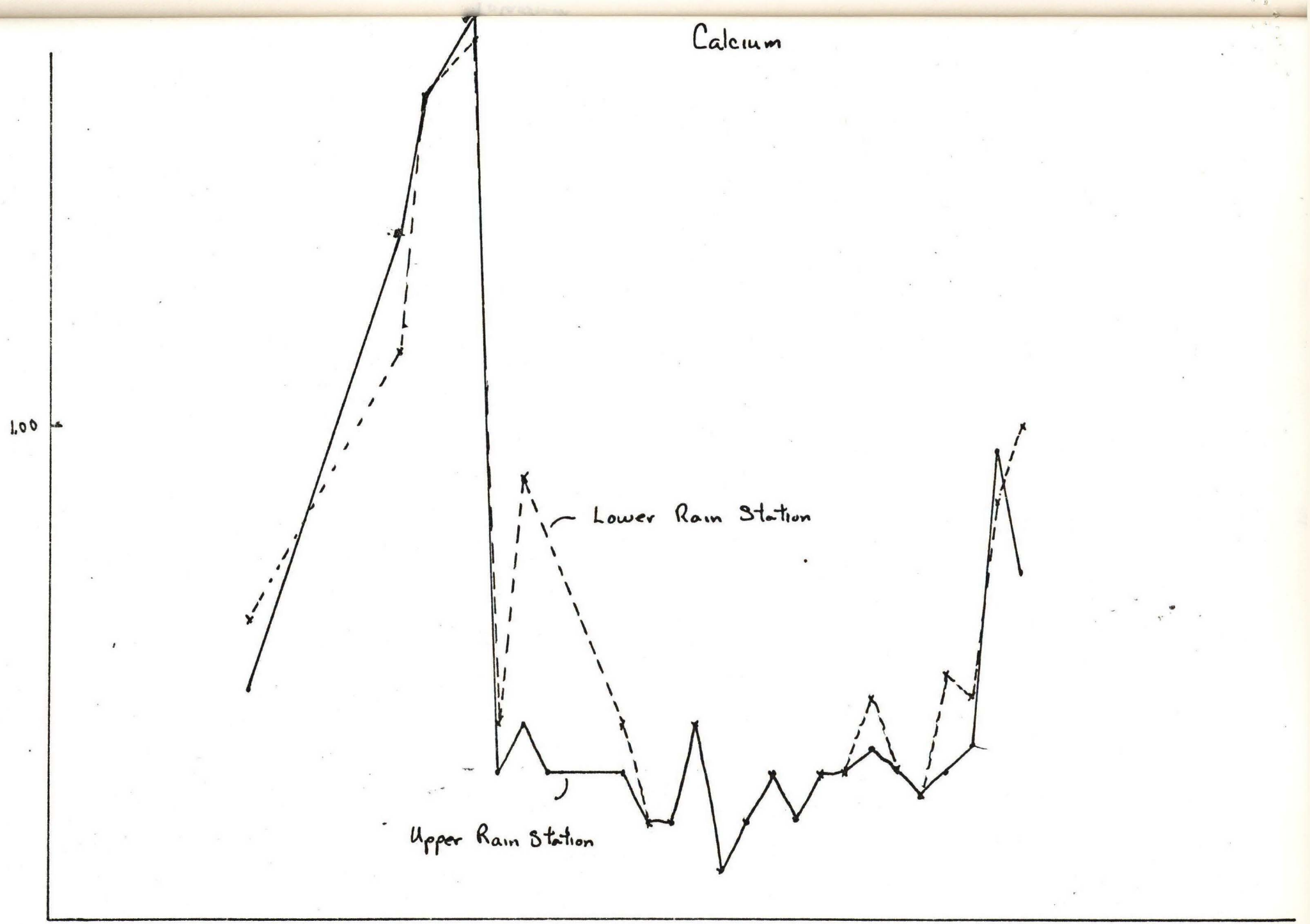

Calcium
3.0
2.0
1.0
Lower Stream Station
Upper Stream Station
J
J
A
S
O
N
D
J
F
M
A
1975
1976

Sodium & Magnesium

Fig. 22a




1.0
K
Lower Rain Station
Upper Rain Station


Calcium
1.00
Lower Rain Station
Upper Rain Station

indicated earlier. Indirect effects of cation changes on organics are probably more significant than direct cation changes *per se*.

V. Conclusions

The foregoing chemical data have clearly satisfied objectives of the study. Table 1 summarizes the data bearing on the first 3 study objectives, (1) chemical characterization of bulk precipitation, and (2) of stream water in an undeveloped and (2) in a developed portion of the watershed. These data allow us to satisfy objective 4, identification of those components most affected by light development. The following generalizations can be made:

1. Light development greatly increases stream levels of alkalinity, orthophosphate, nitrate, calcium, magnesium, sodium, potassium.

2. Light development slightly increases levels of pH.

3. Light development decreases stream levels of total dissolved organics, dissolved organic N, sulfate.

4. Light development has little apparent effect on levels of dissolved organic P, Nitrite, ammonia.

The effects we have observed here are sufficient to have considerable biological impact but not to constitute any human health problem or aesthetic nuisance.

Table 1. Chemical properties of Como Creek in its undeveloped and developed reaches and of weekly bulk precipitation

	pH	alkalinity	absorbance 360 nm	NO_2-N	NO_3-N	NH_3-N	PO_4-P	SO_4	DOP	DON	Conductance
Como Creek undeveloped	6.3-7.5	5.0-14.0	.110-.480	0-3	0-18	0-50	.5-3	.8-4	0-7	0-100	23-35
Como Creek developed	6.5-7.8	5.3-20.0	.090-.460	0-2	0-75	0-65	1.5-8	0-3.5	0-7	0-50	32-44
Precipitation	3.9-6.8	0.5-7.0	.012-.222	1-20	0-900	0-1300	0-140	0-9	0-24	0-1700	8-41